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THE SHIPBUILDING INDUSTRIES OF THE U.S. AND U.S.S.R. AS BASES FOR NATIONAL MARITIME POLICIES: CURRENT CAPABILITIES AND SURGE DEMAND POTENTIAL

Volume I: Main Report

Robert E. Kuenne
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John N. Fry
James H. Henry
John D. Wells
Harry Williams

February 1981

Prepared for

Office of the Under Secretary of Defense for Research and Engineering

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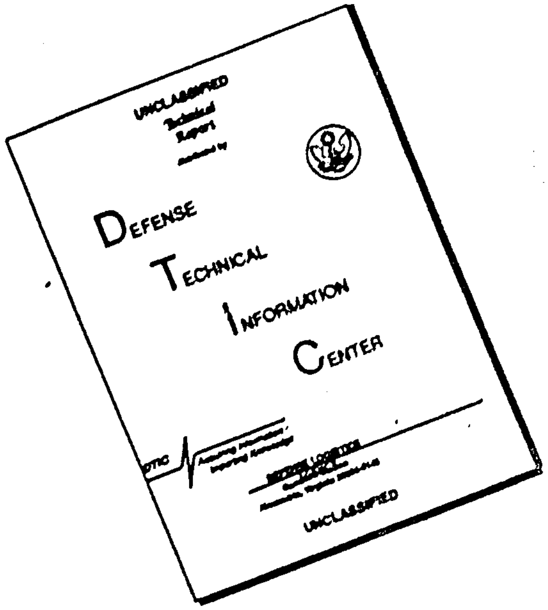

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This study is a comprehensive examination of the U.S. shipbuilding industry and its surge demand potential; it also contains a briefer overview of the Soviet industry, allowing comparisons between the two.
The economic and financial status of the U.S. industry is given detailed treatment. It is concluded that shipbuilding, due to the nature of its product, is an industry which survives in the U.S. only because of direct and indirect subsidization and naval work. Indications are (continued)

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that continuation of recent trends will lead to attrition of yards from the industry in the next decade. Increased profit margins on naval work and more stable yard workloads might reduce this risk.

The physical facilities, labor force, and materials/components supplier base of the U.S. industry are examined with an eye towards those factors which might constrain shipbuilding output. It appears that sufficient facilities exist to accommodate a substantial surge in overall demand. Given time, enough labor is obtainable for a surge, although regional shortages could occur over the short-to-medium term. Priorities, incentives, or outright government production might be necessary to ensure provision of materials, components, and weapons systems. (16-17)

A simulation model ~~was~~ ~~employed~~ to examine the U.S. industry's ability to produce four different naval shipbuilding programs in combination with a commercial estimate. It confirms that the current U.S. industry is capable of effecting significant increases in Navy force levels, although such buildups would require at least ~~ten to seventeen~~ years, depending on assumptions chosen and the actual number and type of ships built. Large or rapid buildups would require re-entry of naval and many repair-only yards into new construction work due to a shortage of nuclear, complex combatant, and large-hull capacity.

The simulation confirms that attrition of yards will occur if current trends in Navy and commercial orders continue. This will affect the above conclusions only if major yards exit the industry.

Cost considerations were not treated.

The Soviet shipbuilding industry is considerably different in structure and conduct from the U.S. industry. The number of large yards is of the same magnitude, but Soviet yards tend to concentrate on production of one or a few ship types. It appears that the Soviet industry is operating much closer to its capacity than the U.S. industry is, but the current rate of Soviet ship output is also much in excess of the U.S. rate.

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PROGRAM ANALYSIS DIVISION
400 Army-Navy Drive, Arlington, Virginia 22202

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PREFACE

The accomplishment of the tasks necessary for this study in the limited time period available made us peculiarly dependent upon the cooperation of a large number of persons. Our acknowledgement of those debts in no way implies that our creditors would agree with the findings and conclusions of the study. We are, nonetheless, deeply grateful for the help and guidance they rendered, at times when they were facing pressing deadlines of their own.

For assistance in the design and execution of the project we are thankful to Robert H. Link, John G. Jardine, and Lawrence Wheeler of NAVSEA. Ronald K. Cooke of NAVSEA and Clarence M. Kunstmann of SESCO, Inc., provided us the four procurement cases we analyzed for the U.S. and were generous in devoting their time to aid us in interpreting them.

Richard O. Thomas, Robert Nevel, and John Hotaling of MARAD provided the estimates of nonmilitary shipbuilding demand, and responded readily to our requests for guidance.

Our analysis of the U.S.S.R. shipbuilding industry was wholly dependent upon intelligence agency data. Bruce Heroth of DIA and Robert Magnan of CIA were extremely helpful in permitting access to this material.

We felt that it was highly important to interview the managements of a large sample of the study-relevant shipyards. Our thanks are accorded to Stuart Adamson of the Shipbuilders Council of America for his rapid and facilitating responses to our requests to arrange such visits. Through his offices,

during the course of the study, we had long and rewarding discussions with the following management officials and their staffs:

Richard Brunner - Avondale
Gayne Marriner - Bethlehem-San Francisco
Archie Dunn - Ingalls
Marty L. Ingwersen - Lockheed
Larry French - NASSCO
William H. Smith - Newport News
Hans Shaefer - Todd, San Pedro
John Gilbride, Jr. - Todd, Seattle

From the generous sharing of their time and the candor of their responses to our questions, the study has greatly benefited, although many of them would disagree with some of our conclusions.

The comforting presence of Dan Mack-Forlist, a consultant, was helpful at all times during the study. We drew upon his deep knowledge of shipbuilding at important points for guidance, and he eliminated errors and deepened insights in his suggestive but effective manner.

Finally, through it all we relied heavily upon the advice and experience of John P. McGough of OSD. Along with cooperation he provided a gentle discipline tempered with encouragement in a rather hectic four-month period.

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GLOSSARY

ABS	American Bureau of Shipping (Specifications)
ASPR	Armed Services Procurement Regulations
CCF	Capital Construction Fund
CDS	Construction Differential Subsidy
CF/CD	Concept Formulation/Contract Definition
CMP	Constant Maximum Program (Shipbuilding Capability Objective)
CONUS	Continental United States
CPIF	Cost Plus Incentive Fee
CRP (Ship Propellers)	Controllable Reversible Pitch
DWT	Dead Weight Tonnage
FD	Forced Draft (Blowers)
FPI	Fixed Price Incentive
FRB	Federal Reserve Board
FYDP	Five Year Defense Plan
GDA	Gross Depreciable Assets
GFE	Government Furnished Equipment
GFM	Government Furnished Material
GRT	Gross Registered Tons
HY 80	High Yield Steel Plate

IDASAS	IDA Ship Allocation System (A Computer Simulation Program)
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LWT	Light Weight Tonnage
MARAD	US Maritime Administration
MIL	Military Specification
MSC	Military Sealift Command
MSRL	Master Ship Repair List
NASSCO	National Steel Shipbuilding Company
NAVSEA	Naval Sea Systems Command
NAVSEC	Naval Ship Engineering Center
NAVSHIPSO	Navy Shipbuilding Scheduling Office
NDA	Net Depreciable Assets
NW	Tangible Net Worth
ODS	Operation Differential Subsidy
PBT	Profit Before Taxes
RO/RO	Roll-On Roll-Off
SHAPM	Ship Acquisition Project Manager
SIC	Standard Industrial Classification
SLEP	Service Life Extension Program (Ship Refit)
SOW	Suspension of Work (Contract Clause)
SS/Swbd	Ship Systems, Switchboard
SUPSHIPS	Supervisors of Shipbuilding

TPP	Total Package Procurement
VMP	Variable Minimum Program (Shipbuilding Capability Program)

NAVY SHIP DESIGNATIONS

AD	Destroyer Tender
AE	Ammunition Ship
AF	Store Ship
AFS	Combat Store Ship
AGOR	Oceanographic Research Ship
AGOS	Ocean Surveillance Ship
AGS	Surveying Ship
AO	Oiler
AOE	Fast Combat Support Ship
AOR	Replenishment Oiler
AR	Repair Ship
ARS	Salvage Ship
AS	Submarine Tender
ASR	Submarine Rescue Ship
BB	Battleship
CG	Guided Missile Cruiser
CGN	Guided Missile Cruiser, Nuclear Propulsion
CV	Conventional Takeoff and Landing Multipurpose Aircraft Carrier

CVN	Conventional Takeoff and Landing Multipurpose Aircraft Carrier, with Nuclear Propulsion
CVV	Vertical Takeoff and Landing Multi-purpose Aircraft Carrier
DD	Destroyer
DDG	Guided Missile Destroyer
FF	Frigate
FFG	Guided Missile Frigate
LCC	Amphibious Command Ship
LHA	Amphibious Assault Ship, General Purpose
LKA	Amphibious Cargo Ship
LPD	Amphibious Transport Dock
LPH	Amphibious Assault Ship, (Helicopter)
LSD	Dock Landing Ship
LST	Tank Landing Ship
MCM	Mine Countermeasures Ship
SSBN	Ballistic Missile Submarine, Nuclear Powered
SSN	Attack Submarine, Nuclear Powered

COAST GUARD DESIGNATIONS

WHEC	High Endurance Cutter
WMEC	Medium Endurance Cutter

MARAD DESIGNATIONS--COMMERCIAL SHIPS

(Numbers Following Designation Indicate Approximate Tonnage)

C-	General Cargo Ship (Number will Indicate Ship Characteristics)
CNTR	Containership
DYB 20, 35...	Dry Bulk Cargo Ship
ITB	Integrated Tug-Barge
LASH	Lighter-Aboard-Ship Cargo Ship
RO/RO	Roll-On Roll-Off Cargo Ship
T 20, 30...	Tanker

EXECUTIVE SUMMARY

BACKGROUND

The deployment of new types of naval combatants by the Soviet Union in the 1970s suggests that the Soviet Navy could emerge in the 1980s as a power projection force similar in make-up to the U.S. Navy. Such a development would pose a threat to the free nations that might have to be met by substantially larger U.S. maritime power. Given the present capacity of the U.S. shipbuilding industry and its resource base, there is some question as to the size of maritime expansion programs that might feasibly be undertaken in the next decade. The Senate Armed Services Committee asked the Department of Defense (DoD) to provide an analysis of the U.S. and U.S.S.R. shipbuilding industries as procurement bases for those nations' navies. Subsequently, the DoD tasked the Institute for Defense Analyses (IDA) under task order No. MDA 903 79 C 0018: T-0-091 (included in Annex A) to perform the current study.

OVERVIEW

This study analyzes the current state of the U.S. shipbuilding industry and its capability to respond to an accelerated construction program. There is also a preliminary look at Soviet shipbuilding capacity and capability to undertake a surge program of large naval combatant construction. The structure of a shipbuilding industry which would be adequate to specified demands, building on the industry as it currently exists, is described in general terms.

Four alternative U.S. Navy shipbuilding programs were provided by DoD agencies through NAVSEA, and MARAD provided a commercial shipbuilding estimate. The four programs afforded us the opportunity to examine the stresses placed on the shipbuilding industry over a 10 to 15 year period of attaining a 500, 600, 700 and 800 ship Navy with average annual new construction orders of 13, 20, 33 and 44 ships. The 1981 force level, as estimated by NAVSEA in 1980, is 546 ships. All these estimates include the Military Sealift Command and some Reserve Units. Other sources of information included government data for the U.S.S.R., and discussions with NAVSEA and MARAD personnel and with executives of several U.S. shipbuilding corporations.[1]

The study was directed at illuminating several questions:

- For each shipbuilding program, how many private and naval shipyards (of the current industry) would be required if each building program were to proceed at a peacetime pace under peacetime constraints?
- For each shipbuilding program, how rapidly could the program ships be built under current conditions? Under conditions just short of mobilization?
- To what extent does the limitation of nuclear capability to a few shipyards affect the number of yards or time required to build a program of so many ships of each general type?
- To what extent does the commercial building program incorporated in the analysis affect the number of yards and time to complete the naval building program?
- To what extent would the substitution of non-nuclear combatant surface ships speed the completion of each of the naval shipbuilding programs?

Consideration of the latter questions was aimed at determining the range of answers to the question of how quickly the shipbuilding industry might expand naval ship output if that were the priority task and if certain "normal" restraints were

[1]Shipyards visited include Newport News, Litton, Todd, National Steel, Bethlehem, Avondale, and Lockheed.

removed--i.e., what would be the "surge" capability of the current and prospective shipbuilding base?

In the analysis a simulation program utilized Navy and industry-supplied descriptions of shipbuilding facilities; Navy and MARAD estimates of the building time and man-hour requirements for various combatant, auxiliary and commercial ships were used. As a base from which to make useful comparisons, NAVSEA supplied an estimate of the scheduling over time and the assignments among yards of each ship in the four programs.

While this study did look at the effect of building all conventionally powered surface ships (rather than some nuclear) on the time to build up under the other constraints, the number and mix of ships in the programs were otherwise taken as given by DoD. Only the facilities of existing yards were used; no consideration was given to the possibility of adding additional facilities/yards.[1] In some cases, however, private yards now devoted entirely to repair work were assumed to resume new construction. The four naval yards still capable of new construction were also used in some cases.

No consideration was given to the question of the shipbuilding industry's adequacy to the task of performing battle damage repairs in actual war. Bringing ships out of mothballs was also not considered.

The numerical feasibility analysis was placed in the context of economic feasibility by an analysis of the current economic and financial status of U.S. private shipbuilding. This additional analysis was designed to highlight a different question from any of those above: Given that one or another of the four shipbuilding programs becomes reality as a national policy

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[1]However, one private yard (Ingalls) was assumed to regain its nuclear qualification in one case.

goal, how will the U.S. shipbuilding industry be impacted in terms of its economic future?

On the basis of these analyses, certain conclusions with regard to the capability of the U.S. shipbuilding industry to support a range of naval building programs can be offered. The objective force sizes which might be selected for the 1990s and some impacts of each building program generated thereby are:

(1) 500-ship force[1]--can be easily accomplished by existing shipyards in 14 years, but probably less than half can be afforded a viable workload. Attrition of numerous small and some large yards would be likely.

(2) 600-ship force--within the capability of the industry, but again implying a shrinkage of the active shipbuilding base.

(3) 700-ship force--would begin to tax the capacity of the industry to accomplish in 14 years, as limited by labor and components supply factors under peacetime conditions. In this program as in the next larger one, the limited number of nuclear-qualified builders delays completion by some years.

(4) 800-ship force--would press upon the physical capacity of all existing private and naval shipyards, including some now devoted to repair. Labor and components could be restricting. Without additional nuclear-qualified builders or the substitution of conventional for planned nuclear-powered surface ships, the program would appear to require in excess of 16 years for completion. The simultaneous employment of various policy options[2] might reduce this requirement to 11 years. The possibility of expanding the shipbuilding industry was not examined.

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[1] The 1981 level is about 546 ships. Totals include Military Sealift Command and some Reserve ships.

[2] Extensive use of priorities for materials and components; government subsidy for or direct production of weapons systems; policies to guarantee sufficient labor to critical yards with local shortages; substitution of conventional surface ships for those which would be nuclear; possible suspension of commercial construction.

Overall, the existing shipbuilding industry, given a reasonably assured long-term building program, can adapt to either lower or higher demand than currently. In the first instance, a shrinkage in the number of firms will occur, and naval ship contract award policies will help determine which firms will survive. If attrition among the large yards were to occur, as seems possible, the industry's ability to respond to surges in demand would be impaired.

In the second case, to guarantee a timely response by the industry will require considering government actions that suspend full dependence on market forces to obtain labor and materials with consequent higher costs. These might include (a) assigning priority to shipbuilding for raw materials and components and enforcing this; (b) suspending competitive bidding in ship construction and going to allocation procedures; and (c) underwriting special recruiting and training programs for shipbuilding skill groups. Resolving the bottlenecks created by a conflict between nuclear-powered ship plans and nuclear-qualified building capacity should be a priority matter for policymakers if a major surge in building is thought probable in the near future.

On the Soviet side, the fact that current major naval ship output exceeds that of the U.S. must be contrasted with the evidence that suggests the industry may be operating nearer its capacity than the U.S. industry. What ought to occasion caution is less the likelihood of a major expansion in combatant output in tonnage terms--or in numbers--but rather the possibility of a change in the mix of types produced. This suggests that additional study of the Soviet industry's capability to alter its output structure is needed along with the kind of information which would permit the kind of simulation analysis which this study used for the U.S. industry.

DISCUSSION

A. THE SHIPBUILDING INDUSTRY

This section will provide a description of the shipbuilding process; it then will summarize the economic analysis of the structure, conduct, and performance of the U.S. industry found in the main report.

1. The Shipbuilding Process

The nature of the typical production process for ocean-going merchant ships and major naval combatants and auxiliaries is implicit in the name of the industry, i.e., "shipbuilding." The process involves construction in-place of the hull, the installation of the major interior machinery and equipment, and the other interior and exterior outfitting. This differs from the construction of a building in that the final construction in-place is preceded by building and outfitting parts of the ship in assemblies (or modules, or blocks) which are then transported to and put together on the shipway on in the dock. At various stages after the hull has reached such a degree of completion as to insure watertight integrity, it is floated (by launching or by flooding the dock) and additional construction and installation are carried out at a fitting dock or pier. Eventually the ship reaches a stage at which it can be powered; the various systems are tested at the dock or pier and, finally, in trials at sea, and the completed ship is delivered to its owners/operators.

The term keel-laying is still used to denote the beginning of construction in the dock or on the shipway, but the procedure of laying a separate keel, succeeded by erection of framing and plating of shell, bulkheads and decks, etc., and the piecemeal installation of machinery and outfitting components and materials was being superceded before World War II

by methods which, in greatly expanded and much more sophisticated forms, are the shipbuilding methods of today. The greatest single impetus for change was the necessity of vastly accelerated construction during the war. The most important technological advance which made this possible was welding.

Great advances have been made since the war. Some examples--special "hot" welding electrodes, plasma cutting and welding, optical lay-out and tape-controlled lofting and cutting, mechanized assembly (panelshops), mechanized semiautomatic frame and pipe bending and semiautomatic assembly of some piping sections and structural members, photogrammetry, computer applications in design and in production control, etc. Many of these innovations were made in the 1950s and 1960s and the process is continuing today with the greatest present emphasis on labor saving and software.

Today the ships are built in a series of assemblies; some may be complete segments of the hull, from bottom to the top deck. These are pre-outfitted to varying degrees, sometimes to the point of plumbing, electrical light fixtures and deck-covering. While this mode of construction--pre-assembly and pre-outfitting--is universal, the degree depends on the facilities of the shipyard and the type and design of the ship.

These methods offer major economies because of the easy access to the work, easier material handling, better access to utilities, elimination of much of the staging and shoring, because the work can be positioned (particularly for downhand welding) and because it permits shorter occupancy, i.e., greater output for the shipyards' most expensive and controlling facility--the building position. The full additional advantage of extensive use of jigs, fixtures and special tools can only be obtained with the construction of series of similar ships.

The process of building the ship and outfitting it involves both complex scheduling and the combining of labor of various skills with flows of raw, semifinished and finished materials, devices and fittings, forgings and castings, parts and systems. These must be put into the ships in a limited number of orderings in time--thus, the delay of one item can theoretically delay the whole process, although there are often alternatives. The installation of the propeller ought to take place before the ship is launched. However, it is possible to do it after launch in drydock, but as this example illustrates, such rescheduling is very often at the expense of additional cost and use of additional facilities.

The process is complex because the ships are put together out of hundreds of thousands of pieces and components, each piece and component going through a number of steps at a number of locations, each step involving a number of people and different tools and processes. There are many millions, in the bigger and more complex ships tens of millions, of actions and events, each interrelated with and interacting with several others. It is this that makes ships complex products and shipbuilding a complex operation.

2. The Structure of the Industry

The horizontal structure of the U.S. industry is characterized by oligopoly, a term used by economists to refer to industries dominated by a few large firms. All measures in Table S-1 reflect the industry's dominance by 25 major shipyards owned by 20 firms (3.3 percent of all shipbuilding and repair firms). These 25 yards are listed in Table S-2 with recent employment levels and potential mobilization employment limits. Figure S-1 geographically displays many of the yards, noting current construction loads of Navy and MARAD projects.

Table S-1. THE PERCENTAGE DISTRIBUTIONS OF FIRMS IN THE SHIPBUILDING INDUSTRY FOR NUMBER, EMPLOYEES, PAYROLL, PRODUCTION WORKERS, VALUE ADDED, AND VALUE OF SHIPMENTS, 1977

Firm Size by Employees	Percent Firms	Percent Employees	Percent Payroll	Percent Production Workers	Percent Value Added	Percent Value of Shipments
1-4	23.1	.1	.1	.1	.1	.1
5-9	11.9	.3	.3	.3	.4	.3
10-19	13.1	.6	.6	.6	.7	.7
20-49	14.7	1.6	1.5	1.8	1.6	1.6
50-99	10.6	2.4	2.3	2.6	2.2	2.5
100-249	11.2	6.1	6.0	6.4	6.7	6.8
250-499	7.6	9.0	8.8	9.2	10.4	10.3
500-999	3.5	8.6	8.8	9.1	10.3	9.8
1,000-2,499	2.6	13.4	14.1	14.0	12.8	14.3
2,500 and over	1.7	57.8	57.5	55.8	54.8	53.6
	100.0	100.0	100.0	100.0	100.0	100.0

Source: U.S. Bureau of the Census [32].

The industry's product structure is similarly concentrated. Table S-3 shows that 97.8 percent of the value of its work comes from the primary activities of shipbuilding and repairing, making it one of the least diversified of industries. Lack of diversification generally makes an industry prone to the oscillations of demand shifts, and shipbuilding is no exception. Further, as Figure S-2 shows, these oscillations are quite large in the case of demand for new ships.

The combination of oligopolistic structure, primary product dependence, and variable product demand puts the industry in a weak and generally unsettled position. Swings in demand are not

Table S-2. RELEVANT SHIPYARDS, BY CATEGORY, WITH CURRENT AND POTENTIAL EMPLOYMENT LEVELS, 1980

Shipyards	Current Employment	Potential Mobilization Employment	Location
Category I. Combatant-Capable (Plus Amphibious/Auxiliary and Merchant)			
1. Bath Iron Works	5,300	12,000	Bath, ME
2. General Dynamics, Quincy	4,900	24,000[a]	Quincy, MA
3. General Dynamics, Groton[1]	22,300	30,000	Groton, CT
4. Newport News Shipbuilding and Drydock	22,400	38,000	Newport News, VA
5. Litton/Ingalls	17,000	21,000[a]	Pascagoula, MS
6. Avondale	7,300	18,000	New Orleans, LA
7. Todd, San Pedro	2,900	8,000	San Pedro, CA
8. Lockheed	2,300	6,600	Seattle, WA
9. Todd, Seattle	3,300	7,200	Seattle, WA
Category I Totals	87,700	164,800	
Category II. Amphibious/Auxiliary-Capable (Plus Merchant)			
1. Sun Shipbuilding and Drydock	4,000	35,000[b]	Chester, PA
2. Maryland Shipbuilding and Drydock	1,300	12,000	Baltimore, MD
3. Bethlehem Steel, Sparrows Point	2,300	15,500[a]	Sparrows Point, MD
4. National Steel and Shipbuilding	6,400	16,800	San Diego, CA
5. Marinette Marine[2]	800	1,200	Marinette, WI
Category II Totals	14,800	80,500	
Category III. Merchant - Capable (Only)			
1. Norfolk Shipbuilding and Drydock	2,000	3,400	Norfolk, VA
2. Alabama Drydock and Shipbuilding	800	5,400	Mobile, AL
3. Tampa Ship Repair and Drydock	1,200	1,400	Tampa, FL
4. Todd, Houston	300	2,300	Houston, TX
5. Todd, Galveston	800	5,000	Galveston, TX
6. Levingston	1,500	4,000	Orange, TX
7. Equitable	800	13,000	New Orleans, LA
8. Bethlehem Steel, San Francisco	1,000	3,500	San Francisco, CA
9. American Ship, Lorain	500	3,600	Lorain, OH
10. Bay Shipbuilding	1,700	1,800	Sturgeon Bay, WI
11. Peterson Builders[3]	700	1,200[a]	Sturgeon Bay, WI
Category III Totals	11,300	44,600	
TOTAL	113,800	289,900	

[1]Combatant-Capable Only (Nuclear Submarines)
[2]Small Combatant/Auxiliary-Capable Only
[3]Recent NAVSEA reassessment indicates that Peterson and Tacoma Boat (not listed) can build small combatants (like PGM) also.

a. These data may be too low.
b. This figure may be too high.

Source: NAVSEA Memorandum.

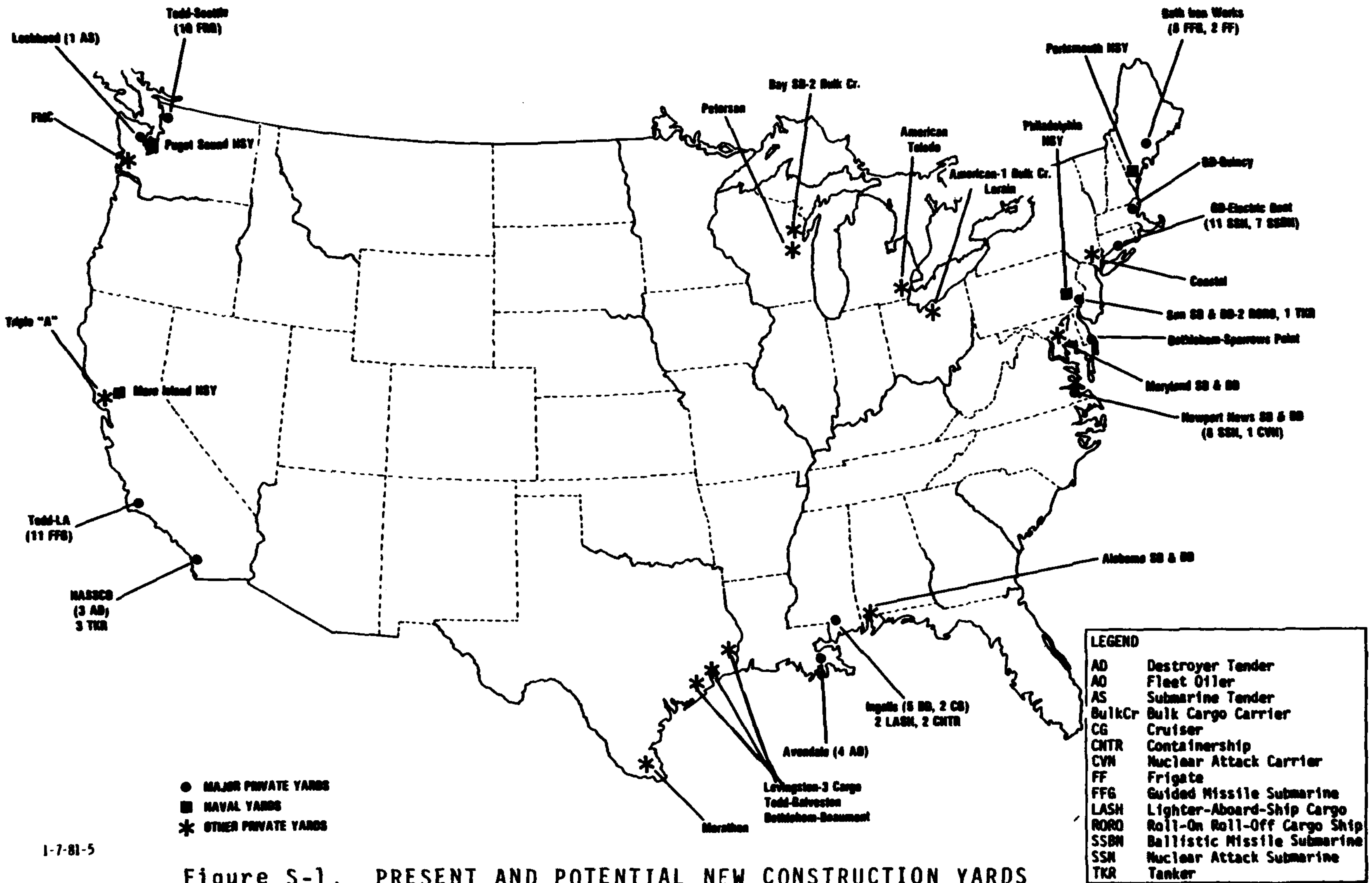


Figure S-1. PRESENT AND POTENTIAL NEW CONSTRUCTION YARDS (SHIPS UNDER CONSTRUCTION, 4TH QUARTER, 1980)

readily accommodated by entry or exit of small firms, as is the case in industries formed by many small competitors; instead, the large firms must find ways to weather hard times while still retaining some ability to take advantage of good ones.

Table S-3. THE PRODUCT STRUCTURE OF THE SHIPBUILDING INDUSTRY, 1977

Product or Service	Value of Work Done (Millions of Dollars)	Percentage of Total Value of Work Done
1. Primary Products		
Self-propelled ships, new, U.S. military	$2,199.4	35.5
Self-propelled ships, new, non military	1,873.9	30.3
Ship repair, conversion, U.S. military ships	705.8	11.4
Ship repair, conversion, non-military	786.1	12.7
Non-propelled ships, new construction	491.1	7.9
Other primary products and services	137.4	2.2
Value of Work Done, Primary Products	$6,193.7	100.0
2. Secondary Products	162.4	---
3. Miscellaneous Receipts	138.9	---
Value of Work Done	$6,495.0	

Source: U.S. Bureau of the Census [32].

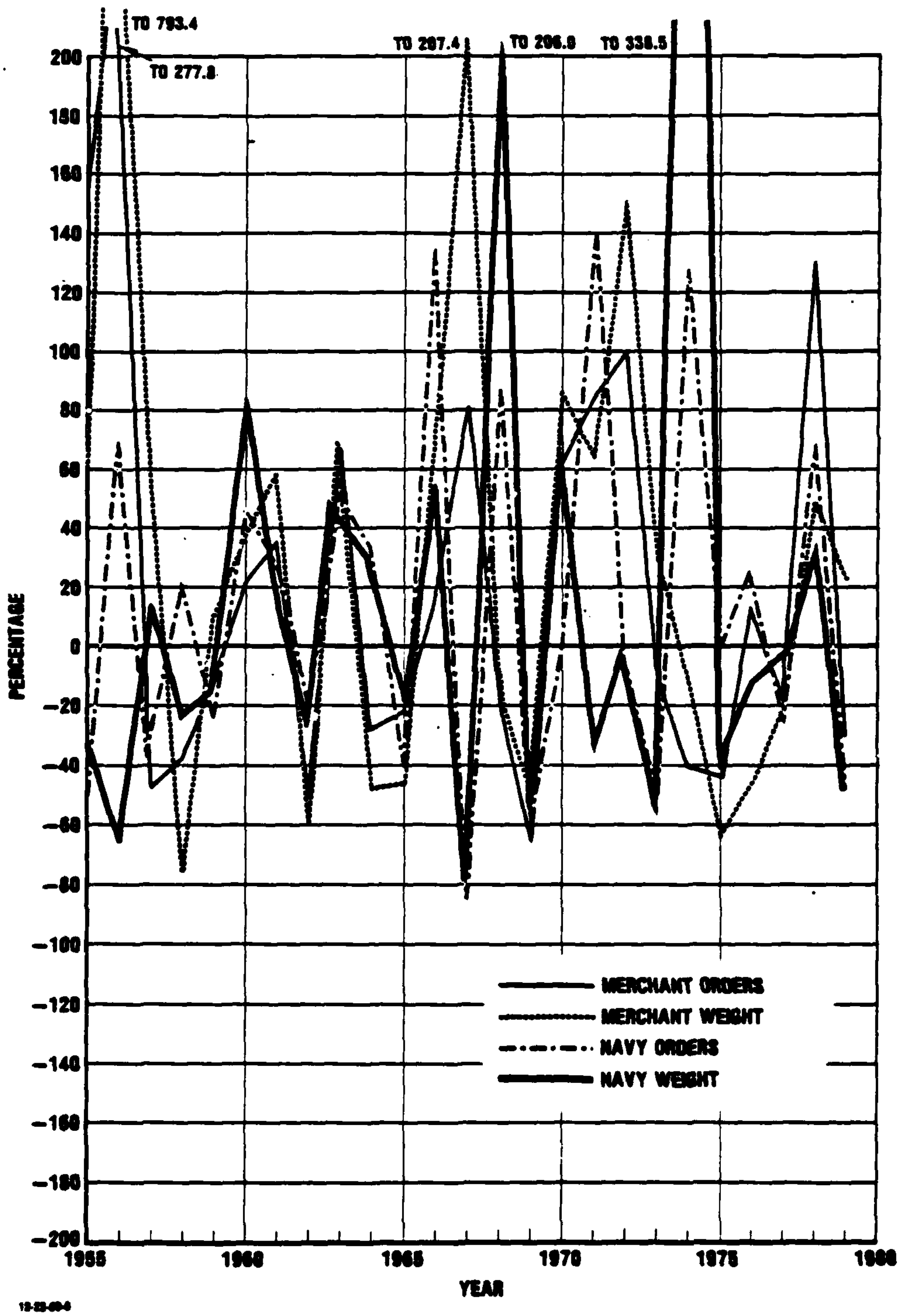


Figure S-2. YEAR-TO-YEAR PERCENTAGE CHANGES IN ORDERS AND DISPLACEMENTS, 1954-1979

This weakness is reinforced by the fact that most new construction orders are either direct purchases by the government (Navy) or are influenced by it through the construction differential subsidy program administered by MARAD. Such monopsony-buyer situations can make effective bargaining by an industry difficult.

Finally, additional uncertainties are introduced by the nature of the industry's relationship with its suppliers (vertical structure). Though Table S-4 shows that much of the cost of a new ship represents value added by the builder, it also indicates that the builder is dependent on a wide variety of industries, but for relatively small fractions of their total product. This often places the shipbuilding industry in the position of the marginal customer who must go to the end of the queue when demand for a supplier's product is high. Figure S-3 shows the resulting huge increases in materials' lead times, which can disrupt shipbuilder schedules at considerable cost.

3. Conduct and Performance

As a rational reaction to the above factors and to the fact that new ships have been customized products to such an extent that series production benefits have been unattainable, the shipbuilding industry is one characterized by low capitalization and labor-intensive methods. Table S-5 shows that out of a sample of comparable industries, shipbuilding afforded its production workers the least capital per capita. Likewise, Table S-6 shows that shipbuilding has the highest payroll as a percentage of value added when compared to similar manufacturing firms, even though it pays one of the lowest wage rates. One would expect the industry to be characterized by low productivity for these reasons, and Table S-7 confirms this. Care must be exercised in drawing conclusions about the *degree* to which shipbuilding lags comparable firms in productivity, since

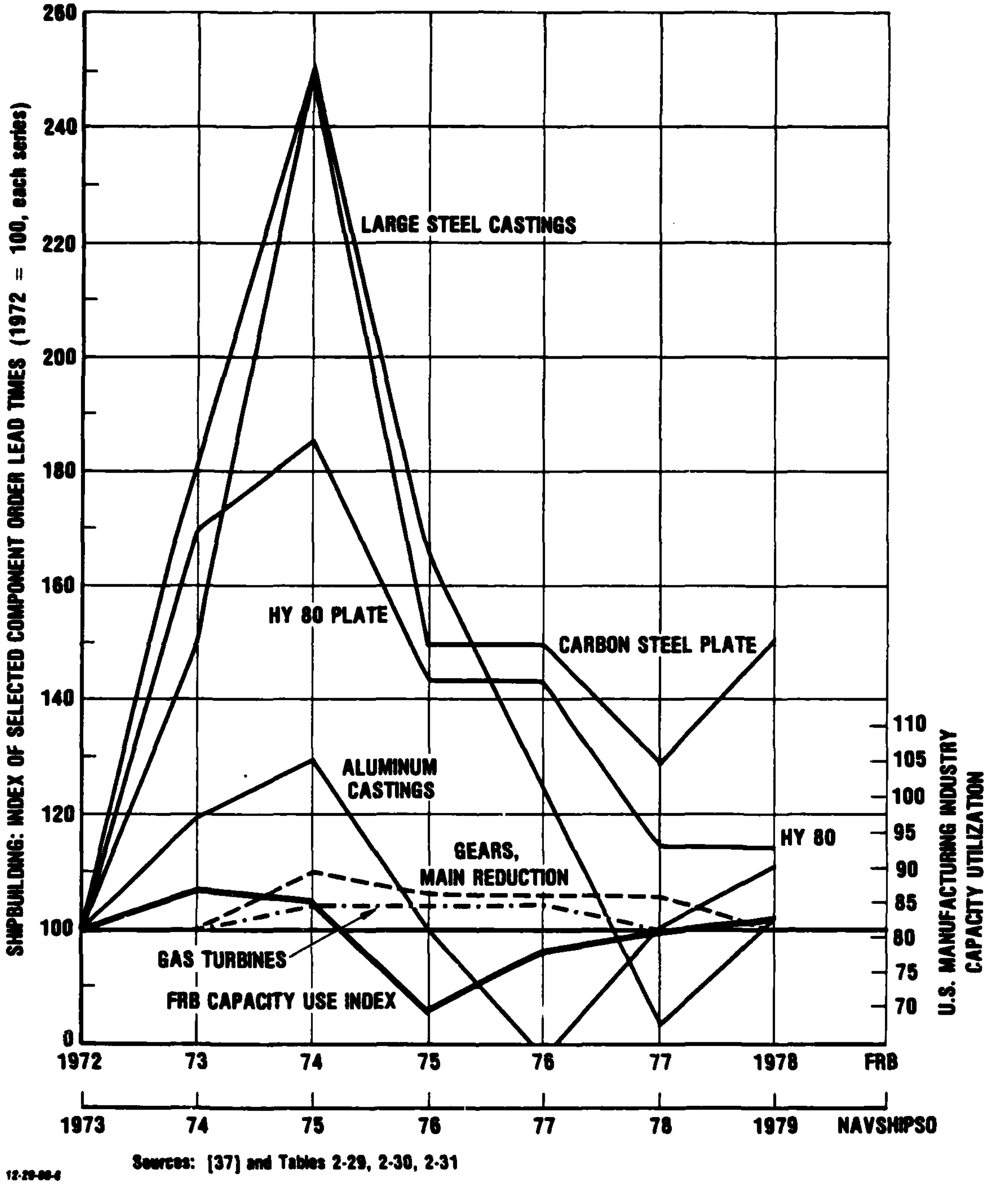


Figure S-3. U.S. MANUFACTURING CAPACITY USE AND ORDER DELAY TIMES

Table S-4. THE INPUT STRUCTURE OF THE SHIPBUILDING INDUSTRY, 1977, IN DOLLARS OF INPUT PER $100 OF PRODUCT

Input	Value Per $100 of Product
1. Carbon Steel	$ 7.75
2. Alloy Steel	.38
3. Stainless Steel	.17
4. Copper	.40
5. Aluminum	.40
6. Metal Castings	.21
7. Lumber	.33
8. Glass Fiber	.09
9. Finishes and Resins	.50
10. Fabricated Plastic and Rubber	.10
11. Fasteners	.25
12. Bearings and Gears	.07
13. Engines and Motors	1.17
14. All Other Materials	22.15
15. Value Added	66.03
Value of Work Done	$100.00

Source: Table 2-7 (main report) and U.S. Bureau of the Census [32].

it is a difficult thing to measure, but the conclusion that it is laggard seems inescapable.

In spite of attempts to cope by laying off and recalling labor as demand for new ships falls and recovers, shipbuilding remains an unprofitable industry. Profitability is also difficult to measure; as an example of the many alternatives quoted in Chapter II, the *Profit '76*[1] study of a set of defense

[1]Reference [41].

Table S-5. GROSS DEPRECIABLE ASSETS, AT HISTORICAL COSTS, EXCLUDING INVENTORIES, AT END OF YEAR, 1975 AND 1976 (MILLIONS OF DOLLARS)

Industry	SIC[1]	1976			1975		
		GDA[2] (Millions of Dollars)	GDA Per Employee (Dollars)	GDA Per Production Worker (Dollars)	GDA (Millions of Dollars)	GDA Per Employee (Dollars)	GDA Per Production Worker (Dollars)
Shipbuilding and Repairing	3,731	2,156.9	$12,968	$16,326	1,808.7	$10,838	$13,558
Aircraft	3,721	2,567.5		22,073	2,458.1	11,171	20,104
Motor Vehicles and Car Bodies	3,711	6,767.0	20,865	24,718	6,333.7	22,420	26,940
Machine Tools, Metal Cutting	3,541	999.6	17,202	26,584	937.2	14,920	22,963
Construction Machinery	3,531	3,168.1	21,876	30,971	2,662.4	17,716	24,490
Fabricated Structural Metal	3,441	1,217.0	12,610	17,085	1,193.4	11,542	15,537
Blast Furnaces and Steel Mills	3,312	33,645.8	74,460	93,981	30,880.5	68,421	87,042
Transportation Equipment	37	28,852.7	17,299	23,935	27,471.5	17,117	24,158

Source: U.S. Bureau of the Census, [32].

[1]Standard Industrial Code.
[2]Gross Depreciable Assets.

Table S-6. VARIOUS INDICES OF LABOR COST IN SHIPBUILDING AND COMPARABLE INDUSTRIES, 1977

Index	Industry (SIC Code)						
	3731	3312	3441	3494	3531	3541	3721
1. Payroll/Employee	$14,136	$19745	$13,228	$13,495	$16,398	$15,981	$17,853
2. Production Workers as Percent of Total Employees	79 79	79 79	73 73	69 69	71 71	73 73	53 53
3. Average Hourly Earnings of Production Workers	$6.52 $6.52	$9.94	$5.80	$6.08	$8.02	$7.08	$7.59
4. Value Added/ Employee	$21,681	$34,694	$25,777	$31,141	$36,986	$31,423	$36,525
5. Payroll as Percent of Value Added	65 65	56	51	43	44	50	49
6. Value Added/Production Worker Hour	$13.80	$22.92	$17.75	$22.63	$27.00	$24.45	$34.96

Source: U.S. Bureau of the Census, [32].

SIC Codes: 3731 - Shipbuilding and Repairing
3312 - Blast furnaces, steel works
3441 - Fabricated structural metal
3493 - Valves and pipe fittings
3531 - Construction machinery
3541 - Machine tools
3721 - Aircraft

Table S-7. REAL VALUE OF SHIPMENTS PER EMPLOYEE FOR A SELECTED GROUP OF DURABLE EQUIPMENT INDUSTRIES, 1972-1976 (IN CONSTANT 1976 DOLLARS)

Industry	1972	1973	1974	1975[a]	1976[a]	Annual Growth Rate
Shipbuilding and repair	$17,302	$20,060	$24,886	$33,270	$31,030	15.7
Automobiles	94,529	99,237	98,600	126,001	173,333	16.4
Aircraft	28,872	34,408	40,754	54,681	60,664	20.4
Aircraft engines and parts	26,384	30,609	35,375	44,441	49,869	17.3
Guided missiles	26,963	30,527	36,878	46,566	44,299	13.2

[a] Estimated.

Source: U.S. Department of Commerce, [40].

industries estimated that shipbuilding firms averaged between four and six percent return on all assets *before taxes* in the period 1970-74, compared with 11 to 18 percent for all firms in the study.

The difficulty of access to capital markets which often results when profitability is poor has been mitigated by the fact that many major yards are now owned by conglomerates (Table S-8), allowing access to internally generated funds. Some concern has been expressed that the growing profit orientation in such corporations may lead them to direct resources away from shipbuilding and into more lucrative ventures. Though this has not occurred, the decision as this report was being written by Sun Co. to cease new construction work at its Chester, Pennsylvania yard for financial reasons may signal the beginning of a new trend.

In conclusion, it is clear that as a product, an ocean-going ship has many qualities that make it unattractive to the private enterprise of a high-wage, advanced-technology, mature industrial nation; that therefore an industry producing ships survives in the U.S. largely through government action (subsidy and naval procurement).

The extreme variability and declining level of demand for ships in recent years have contributed to low capital intensity and high labor turnover in the industry, with consequent low productivity. Poor profitability is imposed by international competition and naval procurement policy.

Without government action to increase and stabilize demand for its product, all indications point toward substantial shrinkage of the industry during the next decade.

Table S-8. OWNERSHIP PATTERN AND YEAR OF ACQUISITION OF CATEGORY I AND CATEGORY II YARDS

Company	Ownership	Year of Acquisition
Category I		
1. Bath Iron Works	Congoleum[a]	1967
2. General Dynamics, Quincy	General Dynamics	1964
3. General Dynamics, Electric Boat	General Dynamics	
4. Newport News Shipbuilding and Drydock	Tenneco	1968
5. Litton/Ingalls	Litton Industries	1961
6. Avondale	Ogden Corporation	1959
7. Todd, San Pedro, Seattle	Independently Owned	
8. Lockheed	Lockheed Aircraft	1959
Category II		
1. Sun Shipbuilding and Drydock	Sun Oil Company	1916
2. Maryland Shipbuilding and Drydock	Fruehauf Corporation	1968
3. Bethlehem Steel, Sparrows Point	Bethlehem Steel	1904
4. National Steel and Shipbuilding	Kaiser Industries - 50% Morrison-Knudsen - 50%	1961
5. Marinette Marine	Independently Owned	

[a]Bath became the basis for the acquisition of Congoleum.

B. ESTIMATING THE RESPONSE CAPABILITY OF THE U.S. SHIPBUILDING INDUSTRY TO SURGES IN NAVAL DEMAND

1. Overview

Table S-9 gives one measure of the excess capacity now present in the industry. It shows that only about half of available building positions are now in use, indicating that a substantial increase in new ship construction ought to be possible if other factors are not constraining.

Table S-9. UTILIZATION OF BUILDING POSITIONS FOR NEW CONSTRUCTION: 1980

Group	Total Positions[a]	In Use	Percent In Use
12 Major Yards	55	39	70.9
15 Shipbuilders	26	8	30.8
Total	81	47	58.0

[a]Electric Boat SSBN and SSN construction and capacity excluded.

Rather than relying solely on such measures, IDA chose to develop a model capable of simulating the employment of shipbuilding industry capacity. Called the Institute for Defense Analyses Ship Allocation System (IDASAS), it allowed a somewhat better determination of current capacity, an estimate of the national security impact of the industry decline projected above, and an exploration of the factors constraining industry output to be made.

Current capacity was explored by using IDASAS to "build" larger and larger case programs of ships in the current industry. When a program could not be completed, capacity had been reached.

The question of the *minimum time* required to complete a buildup was also explored. In an actual emergency, it seems likely that implementing force level increases as quickly as possible would be desirable.

The implications of the impending capacity decline can be explored by determining the *minimum* base necessary to produce the *maximum* buildup envisaged (assuming this is less than or equal to current capacity). If the decline in industry size is not expected to go below this minimum, national security interests are protected.

Unfortunately, the size of the maximum naval buildup for which a base must be preserved was not clear. Rather than making an arbitrary decision about the maximum buildup size, which is a question for policymakers, IDA was provided (by DoD agencies through NAVSEA) with the data for four force level excursions. These included the number of ships by type and a schedule of awards by years. Tables 4-1 and 4-2 in the text summarize these case programs; a more detailed listing may be found in Appendix A, which is classified.[1]

2. Procedure and Results

a. Number-of-Yards Excursions

Drawing from a set of 36 shipyards, IDASAS was used to find the *minimum* number of yards required to reach the FY 1995 force level objective of each program under a variety of labor constraints.[2]

The basic inputs to IDASAS, which allocates ships in order of size and complexity into yards in order of size and qualifications, are:

(1) Number and characteristics of building positions in each yard

(2) Qualification of each yard (nuclear? combatant?)

(3) Employment size and rate-of-increase limits for each yard[3]

(4) Current yard workloads and estimated future repair work

(5) Size, labor requirements, award year, and building time for each ship.

---

[1] An estimate of commercial and Coast Guard requirements, totaling 215 ships over 10 years, was provided by MARAD. It was combined with each of the four naval programs to simulate total loading of the industry.

[2] Force objectives were 518, 581, 700, and 821 ships, respectively. The 1981 force level is about 546 ships, including MSC and some Reserve ships.

[3] Naval yards and very small yards had no employment limits due to a lack of data.

Table S-10. VARIATIONS IN THE MINIMUM NUMBER OF SHIPYARDS REQUIRED (Total Yards Available, 36)

Conditions: Fourteen Years to Reach Force Levels, Fixed (NAVSEA) Award Schedule, Navy Planning Factors

Excursion	CASES			
	Lowest (152 Ships)[b] + Commercial	Base (217 Ships)[b] + Commercial	Intermediate (353 Ships)[b] + Commercial	Highest (457 Ships)[b] + Commercial
1. IDASAS--Minimize Yards				
a. Facilities Limited Only	10	10	16	21
b. Upper Limit on Employment	10	10	19	27[a]
c. Employment Growth--25 Percent Per Year	14	14	22	29[a]
d. Employment Growth--19 Percent Per Year	14	14	27	29[a]
e. Employment Growth--38 Percent Per Year	14	13	21	28[a]
2. IDASAS--Maximized Yards[c]				
a. Navy and MARAD	18	18	32+	36+

[a]IDASAS simulation left significant numbers of nuclear, combatant, and large-hull ships unawarded by 1991 (i.e., force level target is not attained).

[b]Ships built.

[c]Number of yards if objective is to retain maximum number of viable yards out of the group shown in Table S-2.

The number of yards required for each program are shown in Table S-10, Section 1. These results, it cannot be too strongly emphasized, express the full effect of only selected critical factors affecting shipbuilding output, chiefly building positions and labor supply. Thus, all IDASAS results are really *minimum* estimates of the time or number of yards that might be required under normal conditions.

First, as an indication of current capacity, the fact that IDASAS was unable to effect the force level objective of the highest case (due to shortages of nuclear, large-hull, and combatant capacity) when labor constraints are present means that the industry would be hard-put to deliver an 800-ship Navy even in 14 years and using four naval yards for new construction.

Second, the conditions which will lead to failure of yards must be ameliorated soon if the intermediate case is a good approximation of the desired maximum contingency program, and immediately if the highest case is. If a contingency is not seen as realistic, current procurement levels can be supported by a much smaller industry.

It is important to note the crucial role of the large yards listed in Category I of Table S-2. As the analysis in the text will show, these yards are a central part of any program; their failure would especially weaken the industry's ability to respond to a surge in demand.

The parametric excursions around the 25 percent per year employment growth rate constraint show that the results are reassuringly insensitive to its value. However, they also show that it, as well as employment limits, are more constraining than facilities alone.

IDASAS was used to determine the number of yards which could just be supported by each program, with "supported" defined by a minimum viable employment level. These results are shown in section 2 of Table S-10. Of particular interest is the indication that the lowest and base procurement levels, if realized, imply an active industry of *at most* 18 yards, with the probable failure of some major yards. This supports the conclusion reached in the economic analysis.

Further support is given by the results of NAVSEA's own notional assignments of the ships in the four programs, summarized in Table S-11. Often made with different intent than IDASAS runs, the two are directly comparable only in the highest case. Though there is substantial agreement in the number-of-yards results for this case when differences in intent and method are accounted for, the difficulty IDASAS had in attaining the force level target indicates some optimism on NAVSEA's part.

Table S-11. BREAKDOWN OF NUMBER OF YARDS REQUIRED TO BUILD PROCUREMENT PROGRAMS INTO CATEGORY I, OTHER PRIVATE, AND NAVAL YARDS (NAVSEA SOLUTION)

Source / Case	Lowest (152)[a]	Base (217)[a]	Intermediate (353)[a]	Highest (457)[a]
NAVSEA				
Navy Plus Commercial				
Category I	9	9	9	9
All Other Private	14	17	17	21
Naval	1	1	2	4
Total	24	27	28	34

[a]Ships built.

Close examination of the NAVSEA analyses for the two smaller cases shows that a period of furious bidding for the limited numbers of ships (thus the large number of yards used) will be followed by failure of many yards.

b. Time Excursions

Table S-12 gives a generally negative answer to the question of the possibility of significant acceleration of the programs. Though the lowest and base cases could be built considerably faster, the intermediate case's time is unchanged, and the highest case (infeasible above) required 16 years for completion of all of its ships.

Of the accelerating policy options explored, the elimination of commercial/Coast Guard ships (to be built in foreign yards, perhaps) is almost completely ineffective, while going to a conventional surface Navy would save about two years. In a near-mobilization situation (alternative d), with a conventional

Table S-12. MINIMUM NUMBER OF YEARS TO BUILD PROGRAMS

Conditions: Navy Planning Factors (building periods) Award Schedule changed to minimize time.

Variations	CASE			
	Lowest (152 Ships)[1]	Base (217 Ships)[1]	Intermediate (353 Ships)[1,4]	Highest (457 Ships)[1,4]
IDASAS--Minimize Time				
a. 25 Percent Labor Growth	10	12	14	16
b. 2.a., Less MARAD[2] Ships	10	11	14	16
c. 2.b., Surface Conventional Only[3]	9	9	12	14
d. Unlimited Labor,[2,3] No MARAD, Surface Conventional Only	9	9	10	11

[1] Ships built.

[2] Excludes commercial ships.

[3] All nuclear surface combatants in program replaced by conventionally powered ships.

[4] Three or four naval yards used in these cases.

surface Navy, no MARAD work, the guarantee of labor to critical yards, and extensive use of priorities, the time required to complete the larger programs might be shortened to a minimum of ten or eleven years.

The main reason for these still quite long program times is the long building period of the modern warship. Nuclear carriers take eight years, cruisers and submarines six. Thus one cannot hope to build up the Navy in response to any short-term contingency.

These computer results are indicative rather than conclusive. They depend, as noted, mainly on availability of shipways and labor.

The study did not examine possibilities for building more shipyards and the effect that would have on shipbuilding program times. No provision has been made for such possibilities as supplier delays, program changes, financial failure of shipbuilding firms, withdrawal of conglomerates from shipbuilding and closing of yards, or technical difficulties and slippages of schedule for other reasons such as have been common in the past. A definitive estimate of the time required for any program would need to take explicit account of these possibilities.

C. POTENTIAL OF THE SOVIET SHIPBUILDING INDUSTRY

1. The Soviet Industry

Analysis of the Soviet shipbuilding industry is constrained by data availability, by the differences in national economic structures, and by the functional and structural differences in the two nations' navies and merchant marines which could bear upon the relevance of interpretation of the data. (Classified data are given in Appendix B under separate cover.)

Comparative analysis of the U.S./U.S.S.R. industry was therefore imprecise. The social frameworks of the two nations

are different, so economic comparisons are largely unrevealing. Thus, the analysis deals with the physical measures of comparison, recognizing that even these measures are perturbed by the economic structures, product "type" differences and output structure differences.

The Soviet industry has been building ships at an accelerated rate for some time--the number of naval ships produced is impressive (although tonnage is less so), an average of 85 ships per year sustained over 10 years. Non-military ship production is equally impressive at 43 per year. This buildup has occurred in the approximately 270 yards known to exist.

The Soviet merchant marine fleet is seventh in the world in terms of tonnage, and production is spread throughout the home country and the Eastern European Bloc. Much commercial ship production is for export and this activity is aggressively competitive with western nations.

In the last 15 years, the Soviet Union has built 4 new shipyards and improved 24 others. There are some 30 yards in which only naval ships are produced; further, most of these 30 yards specialize in only one category of ship. Total employment in only Navy-relevant yards is greater than that of the entire U.S. shipbuilding industry. Table S-13 compares the relevant elements.

Table S-13. THE NAVAL SHIPBUILDING BASE, U.S. AND THE U.S.S.R.

Country	Total Major Yards	Naval-Ship-Qualified Yards							
		Number	Government	Private	Employment	Number Built Since 1965	Currently Building Naval Ships	No. Ships Under Construction (1980)	Total Large Building Positions[c]
U.S.	51	29	4	25	160,000[a]	1	9	73	103
U.S.S.R.	270	30	30	--	200,000	4	30	150[b]	90

[a]Includes 46,000 in U.S. Navy shipyards who would be assigned to new construction.
[b]Estimated assuming U.S. ratio of ships under construction to output.
[c]Greater than 475' in length.

2. Shipyard Performance

Soviet shipyard performance is again quite difficult to assess in detail given the differences from the U.S. industry. Soviet yards are more vertically integrated than those in the U.S. and ships are more standardized (the latter might indicate potential for greater learning economies). Data indicate that naval yards are operating at or near capacity. However, this cannot be assumed to be a static condition--given mobilization, the Soviets could simply "move" smaller combatants into non-naval yards. Little is known about other factors affecting surge demand--non-naval facilities, labor skill availability, the materials/components supply base, management--all of which could influence Soviet surge capability, for better or for worse.

The U.S.S.R. has produced large numbers of submarines in 5 specialized yards which are nuclear-qualified. Eleven large-combatant-class ships have been produced per year in the last decade, again in what appear to be "specialized" yards. An average of 53 small-combatant-class ships per year have been built in a dozen years; amphibious ship production is quite low at one or two per year.

In naval structure, the Soviets currently have many more ships than the U.S., a ratio of 2 to 1. However, in terms of long-tonnage and accounting for the historic functions of the two navies (previous emphasis by the U.S.S.R. on coastal defense compared with long-range exercise of naval power for the U.S.), the U.S. is superior. In relative strength of carrier fleets, the U.S. is currently far superior.

Comparing production levels of the U.S./U.S.S.R. naval ships, there is a superiority in *numbers* in the Soviet output. This again reflects the structural differences in the navies, for when tonnage (function) is factored in, the U.S. holds the edge.

3. Trends in Output

The U.S. fleet superiority in large combatants, centered on carrier task forces, is not going unchallenged. When we look at trends in output in Table S-14, the shift from equal numbers of major surface combatant ships built for the U.S. in the 1960's and 1970's gives way to a Soviet lead in numbers constructed since 1973. The trend is further illustrated in Figure S-4.

Figure S-4. U.S./U.S.S.R. COMBATANT SHIP PRODUCTION

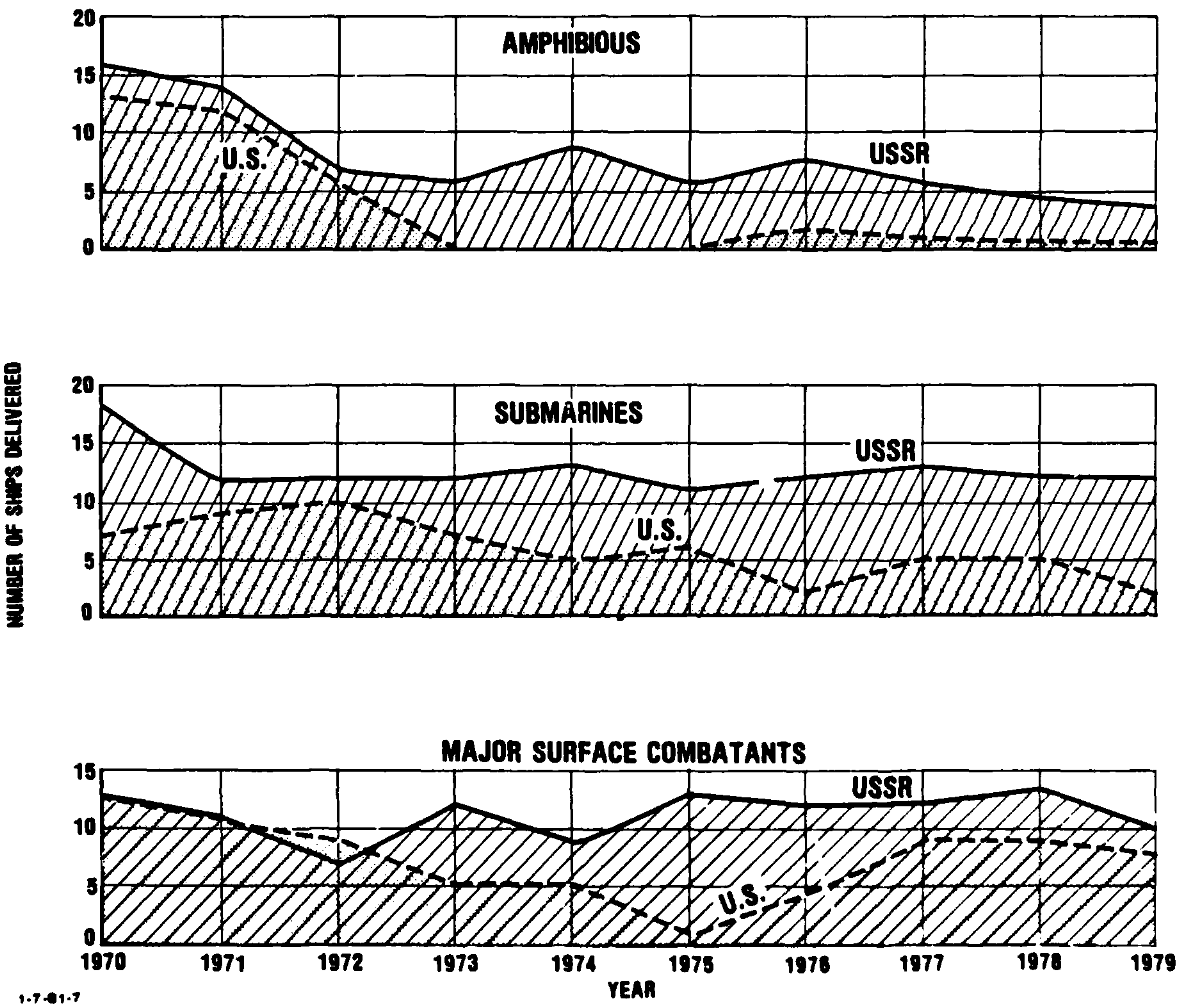


Table S-14. U.S./U.S.S.R. SHIPBUILDING DELIVERIES, NUMBER OF SHIPS

Type	1970		1971		1972		1973		1974		1975		1976		1977		1978		1979	
	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR
1. Major Combatants	12	12	11	11	9	7	5	12	5	9	1	13	4	12	9	12	9	13	8	10
2. Submarines (including conversions)	7	18	9	12	10	13	7	12	5	13	6	11	2	10	5	13	5	12	2	12
3. Amphibious	13	16	12	14	6	8	0	4	0	9	0	4	2	7	1	6	1	5	1	4
Sub-Total (1-3)	32	46	32	37	25	28	12	28	10	31	7	28	8	29	15	31	15	30	11	26
4. Navy Auxiliaries	13	33	10	24	7	23	2	20	0	16	1	15	1	11	0	20	4	15	7	7
5. Merchant and Others	13	75	14	82	19	68	36	86	24	64	19	80	22	70	25	na	19	na	21	na
Sub-Total (4-5)	26	108	24	106	26	91	38	106	24	80	20	95	23	81	25	87	23	80	28	71
Sub-Total (1-5)	58	154	56	145	51	119	50	134	34	111	27	123	31	110	40	118	38	110	34	97
6. U.S.S.R. Small Combatants		64		67		61		48		48		49		51		50		46		48
TOTAL	58	218	56	212	51	180	50	182	34	159	27	172	31	161	40	168	38	156	39	145

D. POLICY OPTIONS

In passing, the study suggests a number of options which might be employed to speed a naval buildup in an emergency. Among them are standardization of Navy ships, the substitution of conventional for nuclear powered surface ships, and extensive use of priorities for materials and components.

However, the focus of the study is on the adequacy of the shipbuilding industrial base, not on how to best employ it in an emergency. Before this adequacy can be finally and thoroughly assessed, policymakers must decide the size and ship makeup of the *maximum* naval buildup the base must be sufficient to provide. Without this, only rough judgments and tentative assessments of options can be made.

Once such a decision is made, there are many policies which might be employed in the maintenance of the base. Multi-year naval procurement to give shipyards a better idea of future workloads; legal changes to increase commercial demand; simple increases in naval procurement: all of these are possibilities, but all should be thoroughly costed before any are chosen.

An example of one rational approach to shipbuilding base maintenance is exemplified by NAVSEA's treatment of the intermediate case. The description from page 4-8 is reproduced here.

> "The intermediate case...is designed to build a number and mixture of ships that will eventually permit a jump to the highest case force level in only five years. This is accomplished in three ways: first, the force level is increased...meaning that fewer ships would have to be built in a hurry; second, Ingalls is assumed to become nuclear-qualified...to alleviate the industry's shortage of nuclear capability; third, it is assumed that the awards are made in a fashion...that results in level-loading of the yards, increasing their financial health and productivity."

Some force level is taken as the maximum to be planned for, and a peacetime program is designed that takes into account the technical limitations that make shipbuilding a very time-consuming process, as well as the necessity to maintain a healthy industrial base.

Again, the costs of this and all other approaches ought to be calculated and compared before a decision is made. Since this study does not consider costs, no specific recommendations can be made.

Chapter I

INTRODUCTION

In June, 1980 the U.S. Senate Armed Services Committee requested the Secretary of Defense to prepare a "detailed assessment of the state of the U.S. shipbuilding industry" in conjunction with the Department of Defense Fiscal Year 1982 budget. To aid DoD in the preparation of this report, the Office of the Undersecretary of Defense for Research and Engineering requested the Institute for Defense Analyses in September 1980 to submit, no later than January 1981, "an analysis of the current state and mobilization potential" of the industry and its supply base, as well as a comparative survey of U.S. and U.S.S.R. shipbuilding potential. This Report is in fulfillment of that task.

The Report is presented in four Chapters. Chapter II details the structure, conduct and performance of the U.S. shipbuilding industry; it gives a concise overview of the myraid factors which have contributed to and influenced the industry and through which it has evolved to its current status.

Chapter III presents a discussion of those physical measures which affect the capacity and expansion potential of the industry. Included in this discussion are considerations of building position capacity, supporting industries' capacity and their expansion capabilities, and an analysis of the labor force and its expansion rate potential. The significance of these potential limits on shipbuilding capacity are presented in the context of responding to surges in demand.

Chapter IV analyzes the sufficiency of the U.S. shipbuilding industry as a procurement base under conditions of surge demand in a contingency mobilization. The analysis uses four specifically defined procurement programs (provided by DoD agencies through NAVSEA) selected for bracketing feasible force structures for 1995 between lowest and highest bounds. Each program (case) seeks to answer two distinct questions: (1) What shipyard, building position, and labor usage is required for each case?; (2) If a set of shipyards is given, what kinds of tradeoffs exist which might allow reduction of the time period over which the program is completed?

The methodology for addressing the questions involve two steps: a formal analysis of the ship-to-yard allocation process within specified constraints using an IDA-designed and developed computer model, IDASAS; and an informal review and modification of the IDASAS results to correct for occasional rigidities or the inability to incorporate some difficult-to-program considerations.

The questions asked and the methodology employed for analyzing the four procurement cases rest on a crucial criterion--a determination of how much shipyard capacity is necessary to preserve a national security base. Such a determination requires an answer to a prior question--what is the expected maximum naval force level that the nation anticipates it might need an industry base to achieve. It is important at this point to explain the two analytical approaches which can be employed in addressing these questions.

One approach can be termed the Constant Maximum Program (CMP) approach. Under it the analyst assumes that some program represents the maximum force level case, and determines the minimum number of yards necessary to achieve it. Under CMP one then uses this highest case subset of yards as that which *must be employed and kept viable in all other cases as well.*

That is, the number of yards in all cases is determined by the highest case, and the question answered by the studies is "What hypothetical allocation of ships among the highest case yard set is best in light of the need to preserve the whole set for the maximum foreseeable contingency?" In CMP the highest case program drives the solution for all programs in that it determines the set of yards to receive allocations.

A second approach is the Variable Maximum Program (VMP) method which assumes consecutively that each case is the maximum force level program. The answers the analyst seeks under VMP are those to the question "If the base (lowest, intermediate, highest) case were the maximum case, what minimum number of yards would be necessary to provide the procurement base?" This is a much different question from that asked under CMP, for it permits the set of yards to vary in size and identity composition from solution to solution. Needless to say, the solutions will differ for the same program in CMP and VMP since they answer different questions.

The analyses in Chapter IV are VMP-inspired. The study team has chosen this approach as it permits policymakers to study the implications of maintaining a procurement base capable of producing naval force levels of varying size, given that that base is defined by the number of yards that must be kept viable. It also gives them a beginning to gauge the costs of maintaining such procurement bases and aids them in their final selection of a maximum force level base for planning. On the other hand, the allocations of ships among a fixed set of yards necessary to the sustenance of those yards under less than the highest case programs would be a set of solutions from a CMP approach.

The answers obtained by this analysis will also provide insights about the capacity of the current shipbuilding industry, and about the national security implications of continuation of recent industry trends.

A separate analysis will consider how quickly naval force levels might be built up, if such actions became necessary or desirable.

Chapter V of this report presents an aggregate comparison of the current status of the U.S.S.R. shipbuilding industry and comparisons of U.S. and U.S.S.R. surge potentials. Much of the data supporting the material of Chapter V are appendicized in a classified supplement.

The analyses presented in this Report suggest certain options which might be considered by government policymakers to facilitate or enable the attainment of the programs analyzed. It should be noted again explicitly that the study does not consider the appropriateness in any national security sense of the programs and hence does not consider surge demand options beyond those explicitly discussed. What is suggested, however, is the strong advisability of costing the VMP solutions and the various options suggested to aid in this determination.

Chapter II

THE ECONOMIC AND FINANCIAL STATUS OF THE UNITED STATES SHIPBUILDING INDUSTRY

In a free market economy, the ultimate security of a nation's military procurement base is grounded in the structure, conduct, and performance of strategic sectors of its industry. Structure has two primary dimensions. The horizontal structure of an industry, reflecting the size distribution of its firms, determines in large part the nature of competition within it, especially as it relates to the conduct of those firms in a bidding or negotiation for government contracts. Vertical structure defines the manner in which the industry obtains its supplies and markets its products--the network of suppliers, subcontractors, and sales mechanisms upon which it is dependent. A view of product and ownership structures completes our survey.

The conduct of an industry encompasses its relations with its competitors and its customers. Most particularly, do firms within it tend to compete fiercely with their industrial peers in bidding procedures, and how do their attitudes differ among customers? What are its typifying relationships with its government and private sector customers? Do those customers possess substantial market power, and if so, how does that possession affect industry behavior?

Finally, the performance of an industry is measured against the market economy's criteria for its survival. Its profitability must be sufficient in the long run to guarantee the industry's access to the investment needed to replace its capital stock and to keep current with technology. That profitability rests more

immediately upon the quality of its management, its flexibility in coping with surge and slack demand periods, and upon its ability to tailor its product mix to its customers' preferences and budgets. In the longer run it is grounded upon the ability to adopt a technology that employs expensive labor efficiently, unless its markets are protected and/or its products subsidized.

In this chapter the concern is with the economic structure, conduct, and performance of the private shipbuilding industry, or, more exactly, with that portion of the industry that builds and repairs blue-water Navy ships and ocean-going merchant marine vessels. Interest is in the current and prospective state of the sector, and therefore is concentrated upon the record since 1970, using it as a basis for projecting into the intermediate-term future. For the most part, analysis is aimed at the aggregate industry level--an overview rather than a detailed firm-by-firm survey--but this focus is narrowed to specific firms, facilities, and supplies in Chapters III and IV.

A. THE SHIPBUILDING INDUSTRY: A STRUCTURAL OVERVIEW

1. The Total Industry--An Orientation

The United States shipbuilding industry--those firms whose primary products are ship construction, conversion, or repair--is at once well-populated with firms yet highly concentrated in important product clusters. The latest available Census of Manufactures (for 1977) lists 610 companies in Standard Industrial Classification Code industry 3731, Shipbuilding and Repairing, only 309 of which had 20 or more employees. It employs about 176,000 people with a payroll of $2.5 billion and with a value of production of about $6.5 billion per year. A marked characteristic of the sector is its single-minded devotion to its primary outputs, for fully 97 percent of its production consists of its two principal products: ships and ship-repair services. As an industry, therefore, it is almost wholly

dependent upon a specialized product mix for its economic health; its facilities and labor skills do not permit much product diversification.

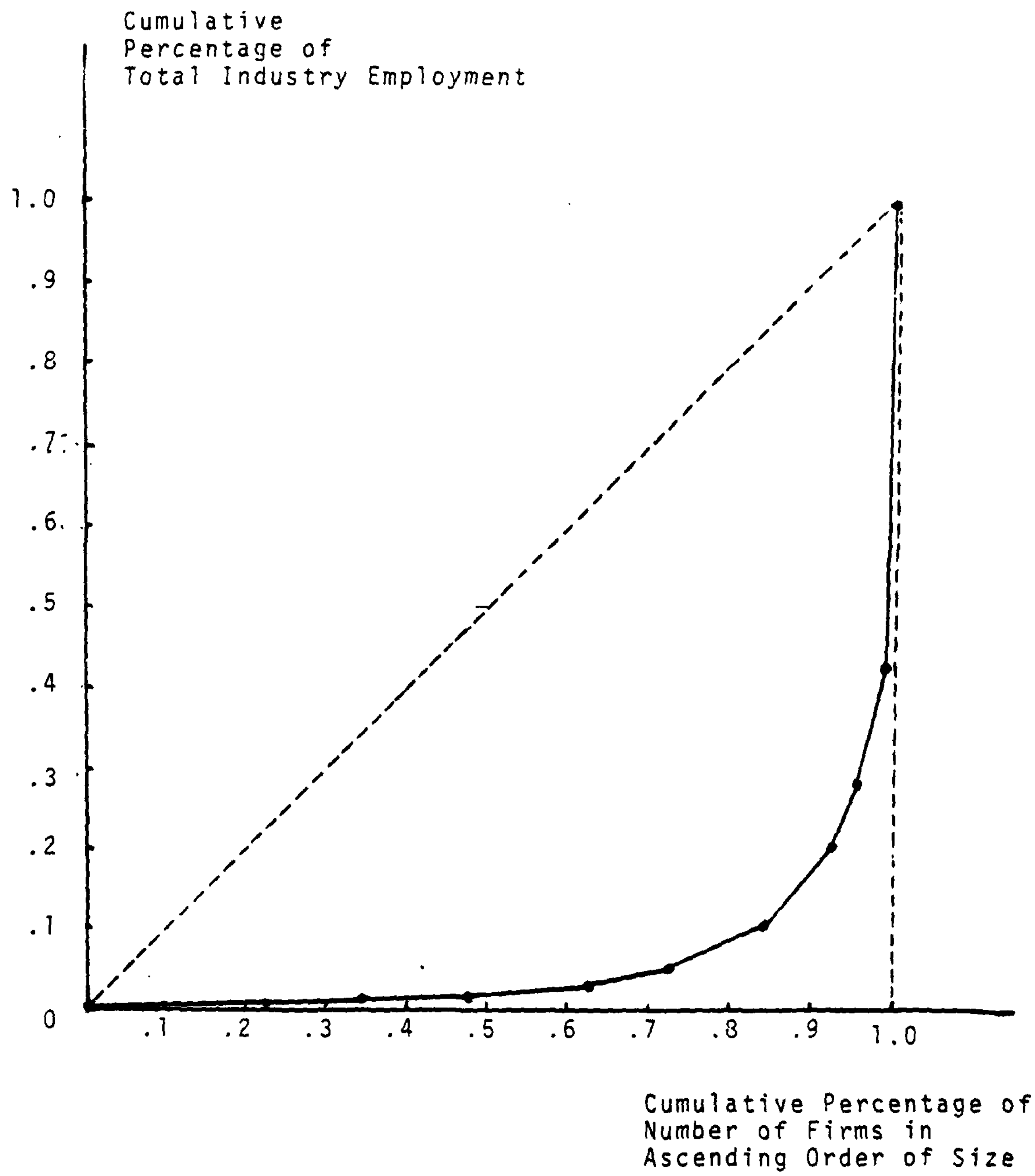
Equally striking is the industry's dominance in terms of employment, payroll, and value of output by a subset of 25 major shipyards owned by 20 firms, or a mere 3.3 percent of the population of firms. This aspect is presented numerically in Table 2-1 and graphically in Figure 2-1.

Table 2-1. THE PERCENTAGE DISTRIBUTIONS OF FIRMS IN THE SHIPBUILDING INDUSTRY FOR NUMBER, EMPLOYEES, PAYROLL, PRODUCTION WORKERS, VALUE ADDED, AND VALUE OF SHIPMENTS, 1977

Firm Size by Employees	Percent of Firms	Percent of Employees	Percent of Payroll	Percent of Production Workers	Percent Value Added	Percent Value of Shipments
1-4	23.1	.1	.1	.1	.1	.1
5-9	11.9	.3	.3	.3	.4	.3
10-19	13.1	.6	.6	.6	.7	.7
20-49	14.7	1.6	1.5	1.8	1.6	1.6
50-99	10.6	2.4	2.3	2.6	2.2	2.5
100-249	11.2	6.1	6.0	6.4	6.7	6.8
250-499	7.6	9.0	8.8	9.2	10.4	10.3
500-999	3.5	8.6	8.8	9.1	10.3	9.8
1,000-2,499	2.6	13.4	14.1	14.0	12.8	14.3
2,500 and Over	1.7	57.8	57.5	55.8	54.8	53.6
	100.0	100.0	100.0	100.0	100.0	100.0

Source: U.S. Bureau of the Census [32].

From Table 2-1 it is clear that the distribution of employees over firms in ascending order of size is a quite close index of the distribution of total payroll, number of production workers, value added, and value of shipments. All



Source: Table 2-1.

Figure 2-1. LORENZ CURVE OF FIRM NUMBERS IN ASCENDING ORDER OF SIZE AND TOTAL INDUSTRY EMPLOYMENT

of these structural indices tend to vary proportionately with number of employees. Conveniently, therefore, employment levels may be used as a single, representative indicator of the industry's horizontal structure.

The unequal distribution of employment over firms classified by size is brought out graphically through the use of a Lorenz curve. On Figure 2-1 the percentage figures for number of firms in Table 2-1 (Col. 1) are cumulated and graphed on the x-axis against the cumulated percentages for number of employees (Col. 2) on the y-axis. The dashed 45° line is the path the graph would take if employment were equally distributed among firms, so that any 10 percent of the firms employed 10 percent of the industry's labor force. The other limiting extreme--of absolute inequality--is depicted by the reverse-L-shaped curve formed by the x-axis from 0 to 1 and the perpendicular dashed line at 1. The departure of the actual distribution from the 45° line and its closeness of approach to the reverse-L curve reveal the dominance of large firms in the industry. From Table 2-1 it is seen that although yards employing more than 1,000 workers account for only 4.3 percent of the industry by number, they employ fully 71.2 percent of the industry's labor force. Broadly, it is this sub-sector of 25 or 26 yards and their suppliers that will constitute the core of interest in this study.

Comparatively speaking, the shipbuilding and repairing industry displays overall concentration ratios that lie at mid-range for a sample of similar metal-forming industries. These ratios are not available at the time of writing for the *Census of Manufactures, 1977*, but it is felt that 1972 *Census* data in these respects will display the current concentration pattern in good approximation. In Table 2-2, therefore, the percentages of value of shipments originating in the 4, 8, and 20 largest firms for shipbuilding and similar industries are listed.

Table 2-2. CONCENTRATION RATIOS IN TERMS OF VALUE OF SHIPMENTS, SHIPBUILDING AND SIMILAR INDUSTRIES, 1972

Industry	SIC[a]	Number of Firms	Percent of Total Industry Value of Shipments		
			Four Largest Firms	Eight Largest Firms	Twenty Largest Firms
Shipbuilding and repairing	3731	415	47	63	81
New construction, military			90	97	99+
New construction, non-military			39	60	83
Aircraft	3721	141	66	86	99
Motor vehicles and car bodies	3711	167	93	99	99+
Machine tools, metal-cutting	3541	857	22	33	55
Construction machinery	3531	644	43	54	72
Valves and pipe fittings	3494	645	11	21	n.a.
Fabricated structural metal	3441	2,010	10	14	23
Blast furnaces and steel mills	3312	245	45	65	84

Source: U.S. Bureau of the Census [31], Vol. 1, Subject and Special Statistics.

[a]Standard Industrial Code.

Military construction is almost as concentrated as motor vehicle production (in 1980, for example, only 9 yards were constructing Navy ships, and only 6 of those were producing combatants). Further, between 1960 and 1978 the Navy let 359 new ship contracts with private yards. Although 22 yards participated, 162 or 45 percent of these ships were constructed by 3 yards: Electric Boat, Newport News, and Ingalls. However, merchant ship and other construction compares favorably with blast furnaces and steel mills, as does overall industry output concentration. The industry as a whole is less concentrated than aircraft or motor vehicle production, on a rough par with construction machinery and blast furnaces and steel mills, and more concentrated than metal cutting machine tools, valves and pipe fittings, or fabricated structural metal.

Despite the large number of firms, therefore, the overall industry's horizontal structure must be characterized as markedly oligopolistic, dictated in large part by the rather small size and specialized nature of the market. As will be shown, no formidable barriers to entry exist, such as large capital requirements or esoteric technological knowhow. The high degree of concentration is markedly true of military construction, somewhat less so for nommilitary. On the other hand, most firms in the industry engage in ship repairing, and except for complex combatants, a vigorous competition characterizes this section of the industry.

2. The Relevant Subsector and Its Structure

As noted above, this overview is primarily concerned with those shipyards that possess the capability of producing ships for the Navy (combatants and amphibious/auxiliary) and/or ocean-going merchant ships (conventionally defined as ships 475 feet or more in length with beams of at least 68 feet). This group of yards numbers 25, and although 7 of them do not employ 1,000 persons currently, all have an estimated potential mobilization labor usage well in excess of that limit. In Table 2-3 are listed these yards of primary interest with their capabilities, current (1980) employment, and potential mobilization employment.

For purposes of this study these 25 yards are classified into three categories:

Category I.	Capable of Building Combatant Ships
Category II.	Capable of Building Amphibious/Auxiliary Ships
Category III.	Capable of Building Merchant Ships.

In general, Category I ship yards are also capable of producing amphibious/auxiliary and merchant ships; General Dynamics' Electric Boat, with its total specialization in nuclear submarines, being the lone exception. Category II yards have merchant

Table 2-3. RELEVANT SHIPYARDS, BY CATEGORY, WITH CURRENT AND POTENTIAL EMPLOYMENT LEVELS, 1980

Shipyards	Current Employment	Potential Mobilization Employment	Location
Category I. Combatant-Capable (Plus Amphibious/Auxiliary and Merchant)			
1. Bath Iron Works	5,300	12,000	Bath, ME
2. General Dynamics, Quincy	4,900	24,000[a]	Quincy, MA
3. General Dynamics, Groton[1]	22,300	30,000	Groton, CT
4. Newport News Shipbuilding and Drydock	22,400	38,000	Newport News, VA
5. Litton/Ingalls	17,000	21,000[a]	Pascagoula, MS
6. Avondale	7,300	18,000	New Orleans, LA
7. Todd, San Pedro	2,900	8,000	San Pedro, CA
8. Lockheed	2,300	6,600	Seattle, WA
9. Todd, Seattle	3,300	7,200	Seattle, WA
Category I Totals	87,700	164,800	
Category II. Amphibious/Auxiliary-Capable (Plus Merchant)			
1. Sun Shipbuilding and Drydock	4,000	35,000[b]	Chester, PA
2. Maryland Shipbuilding and Drydock	1,300	12,000	Baltimore, MD
3. Bethlehem Steel, Sparrows Point	2,300	15,500[a]	Sparrows Point, MD
4. National Steel and Shipbuilding	6,400	16,800	San Diego, CA
5. Marinette Marine[2]	300	1,200	Marinette, WI
Category II Totals	14,800	80,500	
Category III. Merchant - Capable (Only)			
1. Norfolk Shipbuilding and Drydock	2,000	3,400	Norfolk, VA
2. Alabama Drydock and Shipbuilding	800	5,400	Mobile, AL
3. Tampa Ship Repair and Drydock	1,200	1,400	Tampa, FL
4. Todd, Houston	300	2,300	Houston, TX
5. Todd, Galveston	800	5,000	Galveston, TX
6. Levingston	1,500	4,000	Orange, TX
7. Equitable	800	13,000	New Orleans, LA
8. Bethlehem Steel, San Francisco	1,000	3,500	San Francisco, CA
9. American Ship, Lorain	500	3,600	Lorain, OH
10. Bay Shipbuilding	1,700	1,800	Sturgeon Bay, WI
11. Peterson Builders[3]	700	1,200[a]	Sturgeon Bay, WI
Category III Totals	11,300	44,600	
TOTAL	113,800	289,900	

[1]Combatant-Capable Only (Nuclear Submarines)
[2]Small Combatant/Auxiliary-Capable Only
[3]Recent NAVSEA reassessment indicates that Peterson and Tacoma Boat (not listed) can build small combatants (like PGM) also.

a. These data may be too low.
b. This figure may be too high.

Source: NAVSEA Memorandum.

capability as well, with the lone exception of Marinette Marine. The 25 yards are grouped by category in Table 2-3, and henceforth this group is referred to as the "study-relevant" or, more simply, the "relevant" shipyards.

The relevant industry, therefore, breaks down further into "oligopolistic clusters" on the basis of capabilities. Electric Boat is the sole-source producer of Trident fleet ballistic missile submarines, whereas Newport News has a monopoly position for large conventional or nuclear carriers and for other nuclear surface ships. Both firms form a duopoly in bidding for nuclear attack submarines. For other combatants, all 8 Category I yards excluding Electric Boat form a competitive cluster, for they have the potential to seek combatant contracts. These 8 yards are joined by the 5 Category II yards when the product is Navy non-combatants, and 23 of the relevant yards are potential competitors on merchant contracts. Of course, any one of these oligopolistic clusters may number fewer competitors in the bidding on a given contract at a given time because of committed building positions or lack of a specific expertise. That is, a firm may opt out of a competition because it has capacity but no capability for a given ship, or vice versa.

In general, the American shipbuilding industry, dependent as it is on government policy for orders and subsidies, has not been given the degree of direct government guidance or control received by other nations' yards. As a result, this strongest of impulsions toward non-competitive, coordinated behavior has not impacted the American industry. While a strong sense of community is felt among the large firms, and has led to the formation, for example, of the Shipbuilders Council of America as a lobbying trade association, bidding on contracts, especially in periods of slack demand, is fierce. Withholding of relevant information about design plans delivered to follow ship yards is not unknown. Joint research projects are seldom engaged in, exchange of technological information is limited, and no serious

efforts to standardize parts and components have been made. Most of the motivation for the activity that has occurred in these areas has been generated by MARAD in its desire to lower costs in the industry by series production of more standardized merchant ships. MARAD has also funded some of the projects in joint research sponsored by the Society of Naval Architects and Marine Engineers, but these R and D efforts are much smaller than many foreign programs. Collusion among the relevant yards, therefore, is not a problem.

3. The Vertical Structure of the Industry

The relevant shipyards are characterized by very little vertical depth; rather, they are highly dependent upon suppliers, contractors, and Government Furnished Equipment (GFE) for raw materials and components. The modern shipyard has chosen to reduce the number of components produced in its shops in recent times and to specialize in its metal forming and assembly functions. The typical shipyard construction activity is, therefore, one of assembly of externally originated materials and components. In Table 2-4, the cost of materials as a percentage of value of shipments, together with like data for our sample of comparable industries, are listed for 1977.

Although shipbuilding is at the lower end of the range of data in Table 2-4, if the types of shipbuilding activities that are relevant to this study are isolated, the materials percentages are generally much higher, and, where they are not, labor cost (and, therefore, value added) is high. Hence, because the analysis is aimed at obtaining materials cost as value of shipments less value added, and because shipbuilding requires larger proportions of expensive skilled labor, the ratio of materials value to value of shipments is biased downward.[1] To offset this

[1]Because of the long production periods, value of shipments in a calendar year will not correspond with value of work done in shipbuilding. The latter value is the one that is relevant to serve (continued on next page)

Table 2-4. COST OF MATERIALS AS A PERCENTAGE OF VALUE OF SHIPMENTS, SHIPBUILDING AND SIMILAR INDUSTRIES, 1977

Industry	SIC[a]	Materials as a Percentage of Value of Shipment
Shipbuilding and repairing	3731	41
Aircraft	3721	45
Motor vehicles and car bodies	3711	73
Machine tools, metal cutting	3541	37
Construction machinery	3531	54
Valves and pipe fittings	3494	42
Fabricated structural metal	3441	54
Blast furnaces and steel mills	3312	63
All manufacturing establishments		57
Transportation equipment	37	58

Source: U.S. Bureau of the Census [32].

[a]Standard Industrial Code.

bias somewhat, in Table 2-5 are listed estimates of materials cost percentages for the construction of typical vessels.

There is, therefore, a rather strong dependence upon suppliers and subcontractors, with the additional complication for Navy work of GFE. Under this arrangement, the Navy retains responsibility for the acquisition and delivery of these components. As shall be seen, this intermediation of the Navy between yard and supplier has been one of the points of irritation in the relationships between the Navy and the yards.

The supply structure upon which the shipbuilding industry relies is best depicted by the cataloguing of the industry's purchases in 1977, the last year for which detailed data are available. Major supply components, physical amounts where

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(cont'd) as the base of the materials percentage. However, this would have distorted the comparisons with other industries. In 1977, moreover, the two value measures differed by only $77 million, or 1.22 percent of value of shipments.

Table 2-5. MATERIALS AS A PERCENTAGE OF COSTS FOR RELEVANT VESSELS

Type	Materials (Percent of Costs)
Naval	
Auxiliary	59
Amphibious	53
Surface Combatant	55
Submarine	38
Hydrofoil	35
Merchant	
General Cargo	48
Tanker (87,000 DWT)	52.5
Tanker (265 DWT)	45
Roll-on/Roll-off	51.5
LASH (Lighter-Aboard-Ship)	50.5
Container	50.5
LNG (Spherical) (Liquid Natural Gas)	59.5

Source: Lester B. Knight and Associates [16], Vol. II, p. 106.

available, dollar purchases, and percentages of total purchases are given in Table 2-6.

The data of Table 2-6 reveal a heavy dependence upon plates and structural shapes of carbon steel which, value-wise, outweigh all other materials by a factor of 5.8 or more. Engines and motors--predominantly diesel and semi-diesel--are next in importance in a value sense. Alloy steels, copper, aluminum, lumber, and finishes are about equal in importance, but each is only about one-third of the value of engines and motors.

To obtain a better overview of the vertical dependence of the industry, the data of Table 2-6 are grouped into their major numbered categories and the input structure of the industry

Table 2-6. THE VERTICAL DEPENDENCE OF THE SHIPBUILDING INDUSTRY, 1977, BY MATERIALS, PHYSICAL AND VALUE AMOUNTS, AND PERCENTAGES OF TOTAL VALUE

Material	SIC of Supplier	Physical Units	Value in Million Dollars	Value of Material As Percentage of Total Value
1. Steels	33	n.a.	514.3	24.4
a. Carbon	331	1281.7	480.5	22.8
1. Bar and bar shapes	3310	53.2 thousand sh. tons	22.7	1.1
2. Sheet and strip	3310	19.7 " " "	16.9	.8
3. Plates	3310	987.7 " " "	348.8	16.6
4. Structural shapes	3310	183.1 " " "	70.2	3.3
5. Wire and wire products	3310	5.8 " " "	5.5	.3
6. All other carbon steel and forms	3310	32.2 " " "	16.4	.8
b. Alloy			23.4	1.1
1. Alloy steel, except stainless	3310	25.6 " " "	23.4	1.1
c. Stainless steel			10.4	.5
1. Sheet and strip	3310	n.a.	4.5	.2
2. All other stainless steel mill shapes and forms	3310	3.2 " " "	5.9	.3
2. Copper	33	n.a.	24.9	1.2
a. Insulated wire and cable except magnet wire	3357	7.5 million lbs. (copper content)	13.2	.6
b. Copper and copper-base alloys	335	n.a.	11.7	.6
1. Bare wire for electrical conduction only	3357	n.a.	1.1	.1
2. Rod, bar, and mechanical wire, including extruded and/or drawn shapes	3352	1.5 million lbs.	1.4	.1
3. Plate, sheet, and strip, including military cups and discs	3351	1.8 " "	2.3	.1
4. Pipe and tube	3351	5.9 " "	6.9	.3
3. Aluminum and aluminum-base alloy	335	20.6 " "	24.5	1.2
a. Sheet, plate and foil	3353	14.5 " "	17.2	.8
b. Extruded shapes, including bar, pipe, etc.	3354	5.4 " "	6.2	.3
c. All other mill shapes and forms wire, rolled rod, etc.	3350	.7 " "	1.1	.1

Table 2-6 (continued)

4. Metal castings, rough and semifinished	33	n.a	13.1	.6
a. Steel	3320	8.2 thousand sh. tons	11.7	.6
b. Aluminum and aluminum-base alloy	3361	.3 million lbs.	.5	-
c. Copper and copper base alloy	3362	.3 " "	.9	-
5. Lumber	24	n.a.	21.1	1.0
a. Pressed lumber	2421	25.3 million bd. ft.	12.5	.6
b. Plywood	2430	n.a.	8.6	.4
6. Glass fiber, all types	3229	7.8 million lbs	5.3	.3
7. Finishes and resins	28	n.a.	31.2	1.5
a. Plastics resins consumed as granules, pellets, powders, liquids, etc.	2821	9.3 " "	4.2	.2
b. Paints, varnishes, lacquers, and enamels	2851	n.a.	27.0	1.3
8. Fabricated plastic and rubber products	30	n.a.	5.9	.3
a. Fabricated rubber products, except tires, tubes, hose, belting, and gaskets	3069	n.a.	2.2	.1
b. Plastic products consumed as sheets, rods, tubes, and other shapes	3079	n.a.	3.7	.2
9. Bolts, nuts, screws, rivets, and screw machine products	3450	n.a.	15.6	.7
10. Bearings and gears	35	n.a.	4.3	.2
a. Ball and roller bearings	3562	n.a.	2.0	.1
b. Speed changers, drives, and gears	3566	n.a.	2.3	.1
11. Engines and motors	35, 36	n.a.	72.4	3.4
a. Diesel and semi-diesel	3519	1,800	53.2	2.5
b. Integral horsepower electric motors (1 HP and over)	3621	n.a.	13.5	.6
c. Engine electrical equipment, including spark plugs, magnetos, generators, starters, etc.		n.a.	5.7	.3
12. All other materials, components, parts, containers, and supplies	97	n.a.	1373.6	65.2
TOTAL			2106.2	100.0

Source: U.S. Bureau of the Census, [32].

is displayed. The numbers in Table 2-7 reveal the sources in dollars of each $100 in shipbuilding product.

Table 2-7. THE INPUT STRUCTURE OF THE SHIPBUILDING INDUSTRY, 1977, IN DOLLARS OF INPUT PER $100 OF PRODUCT

Input	Value/$100 of Product
1. Carbon Steel	$7.75
2. Alloy Steel	.38
3. Stainless Steel	.17
4. Copper	.40
5. Aluminum	.40
6. Metal Castings	.21
7. Lumber	.33
8. Glass Fiber	.09
9. Finishes and Resins	.50
10. Fabricated Plastic and Rubber	.10
11. Fasteners	.25
12. Bearings and Gears	.07
13. Engines and Motors	1.17
14. All other Materials	22.15
15. Value Added	66.03
Value of Work Done	$100.00

Source: Table 2-6 and U.S. Bureau of the Census [32]. There are some unexplored discrepancies among value added and materials consumed figures that are displayed in different documents of the preliminary Census reports. These account for the discrepancy in the latter implied by the above data and that implied in Table 2-4.

The overwhelming dominance of carbon steel is evident from Table 2-7, as well as the large value of miscellaneous materials whose individual components make small value contributions. If one begins the search for potential choke points in the supplying industries, therefore, the task must be undertaken with some

care, for this omnibus category includes many items of highly fabricated, technologically complex GFE. There is no reason, of course, for materials bottleneck probabilities to be positively correlated with relative values in the input structure. Indeed, the smaller the dollar amounts of a component taken by the industry, the more likely that the supplying industry may find it unattractive to produce.

4. The Product Structure of the Industry

The total product of the shipbuilding industry is best categorized under six headings. These are defined in Table 2-8: the distribution of the value of work done in 1977 over these product classes is displayed.

Almost two-thirds of the yards' income from the sale of primary goods and services is obtained from new construction of self-propelled ships. When non-propelled ships such as oil rigs are added, this total rises to almost 75 percent. About 36 percent of primary output consisted of new ships for the Navy, which were under construction in only nine of the industry's firms. Only 6 Category I shipyards worked on combatant construction and only 3 Category I yards produced amphibious/auxiliary ships. Only 1 Category II yard produced these support ships. Hence, 9 yards accounted for 36 percent of the industry's primary output.

Nonmilitary self-propelled new construction was almost as important as military, and, of course, was more widely dispersed among firms than military. Nonetheless, the concentration of work in Category I, II, and III yards is, of necessity, great, given that ocean shipping can only be built in them. For example, between 1957 and 1975 the Maritime Administration subsidized 243 ships. Of that total, the 9 Category I yards received 149 or 61 percent of the ship awards, Category II yards 84 or 35 percent, and Category III yards (including those which went bankrupt in the period) the remaining 10, or 4 percent. In

Table 2-8. THE PRODUCT STRUCTURE OF THE SHIPBUILDING INDUSTRY, 1977

Product or Service	Value of Work Done (Millions of Dollars)	Percentage of Total Value of Work Done
1. Primary Products		
Self-propelled ships, new, U.S. military	$2,199.4	35.5
Self-propelled ships, new, nonmilitary	1,873.9	30.3
Ship repair, conversion, U.S. military ships	705.8	11.4
Ship repair, conversion, nonmilitary	786.1	12.7
Non-propelled ships, new construction	491.1	7.9
Other primary products and services	137.4	2.2
Value of Work Done, Primary Products	$6,193.7	100.0
2. Secondary Products	162.4	---
3. Miscellaneous Receipts	138.9	---
Value of Work Done	$6,495.0	

Source: U.S. Bureau of the Census [32].

October 1979, MARAD's Title V subsidized contracts not yet completed totaled 30 with a value slightly in excess of $2 billion. Fully half of these contracts with 68 percent of the total value were in Category I yards. Indeed, Quincy, Avondale, and Newport News accounted for most of these amounts. Category II yards had 5 of the 30 with 18 percent of the value and the remainder were in Category III yards.[1] Although, of course, not all ocean-going merchant vessels are MARAD-subsidized and non-category yards produce smaller self-propelled ships, the concentration of primary production in nonmilitary new construction is marked.

[1]U.S. Maritime Administration [38], p. 78.

A notable feature of Table 2-8 is the degree to which the workload of the industry depends upon repair and conversion work. Almost one-quarter of its revenue is so generated, about equally divided between military and nonmilitary uses. Currently, government policy by Congressional dictate is to allocate about 70 percent of Navy repairs and conversions to the eight naval shipyards and 30 percent to commercial yards (for all practical purposes, Category I, II, and III yards). The basic reason for this policy is to maintain these category yards as a Navy procurement base by supplementing new construction revenue and helping to lessen the instability of the yards' workloads which reflect what has been a highly cyclical demand for both types of customer for new ships.

The interest of this study in conversion and repair is, for the most part, derived from their potential as competitors for shipyard building positions and labor in periods of extremely rapid Navy and/or merchant fleet buildup, although in ordinary circumstances they rarely require building positions. It must, therefore, be included in the feasibility studies of the four programs which will be analyzed in Chapter IV with the aid of the IDASAS. This is not to denigrate their importance as a contribution to such economic health as the industry enjoys, as the data of Table 2-8 reveal, and these services will be considered in more detail in the discussion of product characteristics in Section B.

5. Ownership Patterns and Management

Shipbuilding, as will be shown, is not a capital-intensive industry, since fixed capital is long-lived and relatively modest in quantity, and progress payments relieve the firm of the burden of much of the work-in-progress inventory that cumulates over the long production periods for ships. Historically, therefore, the industry has featured small companies and corporations, until recent times most frequently managed by "hardware-oriented"

production men. In the postwar period, however, notable changes in ownership and management of the larger relevant companies have occurred.

Since 1959 all of the Category I yards but Todd Shipyards--which remains independent--have been acquired by multicompany corporations, many of them horizontal conglomerates. In Table 2-9 are listed the ownership of the Category I and II yards and the year of their acquisition.

Table 2-9. OWNERSHIP PATTERN AND YEAR OF ACQUISITION OF CATEGORY I AND II YARDS

Company	Ownership	Year of Acquisition
Category I		
1. Bath Iron Works	Congoleum[a]	1967
2. General Dynamics, Quincy	General Dynamics	1964
3. General Dynamics, Electric Boat	General Dynamics	
4. Newport News Shipbuilding and Drydock	Tenneco	1968
5. Litton/Ingalls	Litton Industries	1961
6. Avondale	Ogden Corporation	1959
7. Todd, San Pedro, Seattle	Independently owned	
8. Lockheed	Lockheed Aircraft	1959
Category II		
1. Sun Shipbuilding and Drydock	Sun Oil Company	1916
2. Maryland Shipbuilding and Drydock	Fruehauf Corporation	1968
3. Bethlehem Steel, Sparrows Point	Bethlehem Steel	1904
4. National Steel and Shipbuilding	Kaiser Industries - 50% Morrison-Knudsen- 50%	1961
5. Marinette Marine	Independently owned	

[a]Bath became the basis for the acquisition of Congoleum.

The primary period of acquisition was clearly the late 1950's and 1960's in the conglomerate craze. Four of the mergers occurred in the 1960 recession (Ingalls, Avondale, Lockheed, and NASSCO) when backlogs were low and several yards were known to have financial and/or family control problems (e.g., Ingalls) or felt the need to obtain a larger financial base for expansion (e.g., Avondale, NASSCO). The motivations for the acquisitions are still not clear, but a number seemed to have played some part:

(1) The relatively cheap prices of the yards, together with the ability of the acquiring companies to finance the purchases by stock and debenture issues.

(2) The generous progress payments policy of the Navy. Until 1970, it made routine weekly partial payments for costs incurred. Since the yards typically paid bills monthly, an attractive cash flow existed.

(3) The desire of technology-oriented conglomerates like Litton to extend their methods to shipbuilding, especially with the opportunities afforded by the total package procurement policies of the McNamara era.

(4) The prospective rise in demand for tankers when Alaskan North Slope oil was lifted, as well as LNG tanker prospects.

(5) The existence of tax loss carry forward potential in many of the yards.[1]

One of the important changes wrought upon the relevant shipyards by the multicompany absorptions was the accession to management of much more aggressive, profit-oriented, cost-conscious leaders. On the one hand, the acquisition movement led to substantial investments in new, modernizing capital in the industry, permitting yards like Newport News, Ingalls, Avondale and NASSCO to become or retain their position as leaders in the industry. On the other hand, the new management strengthened the yards' stance in contesting claims adjustments, management practices, and profit margins with the Navy. The new managements seem

[1]For a fuller treatment of the impacts of the acquisitions on the industry, see G. L. Kavanaugh [15].

unquestionably to have played an important role in the development of the marked adversary relationship that arose during the 1960's and 1970's between the yards and the Navy, originating in part in nuclear construction and exacerbated by McNamara's procurement policies. It continues, though much less intensely, at present.

Additionally, the new management infusion raises several questions about the future of the relevant yards. The possibility that cash flows will be "pooled," so to speak, over the component profit centers of a multicompany organization and that investment projects will be chosen on a descending prospective rate-of-return basis could be damaging to the shipbuilding industry. Although there is little sign that this has occurred in the past--indeed, quite the opposite seems true--the increased "professionalization" of management with its proper emphasis upon profitability may well result in the future in a phasing out of new construction capacity.

B. THE NATURE OF THE INDUSTRY'S PRODUCTS AND PRODUCTION

If one were to design a product whose characteristics combined the qualities least attractive to private enterprise in a high-wage, advanced-technology, mature industrial nation, that product would closely resemble an ocean-going ship. Indeed, the product is ideally suited to create a problem industry, and it is a tribute to the industry's management--and government policy--that its base remains as substantial as it is. The analysis turns, therefore, to the economically relevant characteristics of this industry's product mix.

Imagine a product which is extremely durable (25 years or more), built in small quantities at high unit cost, uncompetitive in all but protected domestic markets, and whose design is essentially out of the control of its producer. Its high labor cost reflects in part its nonsusceptibility to mass production

methods and the high skill levels required to build it to tailor-made specifications that must meet rigorous Navy, Coast Guard, Health Service, Customs Service, Maritime Administration, American Bureau of Shipping, and American Institute of Electrical Engineers standards. The production period for the product has a time span measured in years, during which rip-out of completed work may be required to meet changed designs. Economic production requires tight time phasing of a wide variety of skills, materials, and facilities, yet most of the components are supplied by firms whose schedules may not mesh with the producer of the product, and some of which may be beyond the sanction of the producer. Finally, imagine fully half of the product produced for a customer with sole-buyer pricing power who feels obliged to move a portion of his own management on site to complicate lines of authority with the producer's management and multiply delays and paperwork. That product is an ocean-going ship. These characteristics are developed in more specific detail.

1. Characteristics of the Industry's Outputs

As has bee shown in Table 2-8, the U.S. Navy's new construction program generates about 36 percent of the value of work done in recent years by the industry, and, of course, for many Category I and II yards a much larger percentage. Because it constitutes about 54 percent of new construction, it shall be considered first.

a. Navy Ship Construction

Perhaps the most striking feature of the Navy ship is the length of the production process, both planned and actual. In Table 2-10 are presented actual average pre-construction and construction intervals for combatants and the LHA, as well as the planned magnitudes at the time of contract award.

Table 2-10. AVERAGE PLANNED AND ACTUAL CONSTRUCTION AND PRE-CONSTRUCTION INTERVALS FOR A SAMPLE OF U.S. NAVY SHIPS

(In months)

Ship Type (Number in Sample)	Planned	Actual	Pre-Construction Intervals Award to Start Construction		Construction Intervals Start to Keel Laying		Construction Intervals Keel Laying to Launch		Construction Intervals Launch to Delivery	
			Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual
SSN-688 (5)	52.0	77.4	10.4	10.4	9.0	11.2	19.4	31.2	13.2	24.6
CGN (3)	48.7	67.7	7.7	10.0	7.7	11.7	17.0	21.7	16.3	24.3
CVN (3)	71.6	86.7	5.7	4.3	5.3	6.7	37.3	50.0	23.3	25.7
DD-963 (7)	58.0	70.4	39.1	29.3	1.6	4.0	9.6	13.1	7.7	24.0
LHA (3)	40.5	91.7	17.0	21.3	2.0	8.7	14.5	33.0	7.0	28.7
FFG-7	46.4	48.1	14.3	11.8	5.0	6.5	11.3	13.5	15.8	16.3

Source: NAVSEA Report # 250-574.

On the basis of these samples, actual building position occupancy, measured from the date ship sections move into a building position to launch of the ship, averaged 31 months for nuclear attack submarines, 22 months for nuclear guided missile cruisers, 50 months for a nuclear strike carrier, 13 months for a Spruance-class destroyer, 33 months for a helicopter assault landing ship, and 14 months for a guided missile frigate. As can be seen from Table 2-10, adding on both ends the preliminary and post-launch construction activities, the latter including substantial outfitting activity, lengthens the total production times by three years or more. In all ships' construction intervals and most preconstruction intervals, Navy planned lead times were overly optimistic.

Current NAVSEA planning factors for a sample of combatant and amphibious-auxiliary ships are given in Table 2-11. Where comparable ship types to those in Table 2-10 are displayed it may be seen that planned lead times have come into closer congruence with historical times. Total estimated times remain between two and six years, with nuclear carriers an outlier at almost eight years. Note that three to four years is characteristic for those Navy ships that are closest in configuration to merchant ships.

These long lead times contribute to the existence of a second characteristic that is universally viewed as unfortunate if inevitable. This is the frequent necessity to rip out completed work to institute new technology or, given the complexity of the component systems, to correct unforeseeable errors or incompatibilities. Also, because of Defense Production Act requirements, it may be necessary to transfer labor from non-priority construction, disturbing the programming of those projects, to effect such changes. The difficulty of costing these interruptions has been a major factor in claims disputes between the yards and the Navy.

Table 2-11. NAVSEA PLANNING FACTORS FOR CONSTRUCTION AND PRE-CONSTRUCTION INTERVALS FOR A SAMPLE OF U.S. NAVY SHIPS

(In Months)

Ship Type	Pre-Construction			Keel Laying to Launch	Launch to Delivery
	Total	Award to Start Construction	Start to Keel Laying		
SSN-688	67	12	14	23	18
SSBN	72	12	14	30	16
CG-47	52	10	6	15	21
CVN	94	12	14	43	25
FFG-7 (Bath)	46	18	8	8	12
FFG-7 (Todd-San Pedro)	47	18	6	8	15
FFG-7 (Todd-Seattle)	48	10	4	9	25
LSD-41	52	12	6	16	18
MCM	36	12	4	10	10
AD	49	12	4	17	16
AOR	46	12	5	17	12

Source: NAVSEA Memorandum.

This factor, in turn, contributes to a third characteristic: the difficulty of applying true mass production methods to Navy ship production. Each ship within a series takes on some aspects of a new product with its own peculiarities. The production of follow-ships in a series in a new yard enforces modifications to meet the needs of that yard's facilities. The characteristic leads to shallow learning curves, or, indeed, invalidates the use of learning curves in many cases. The yards continue to question the need for follow-ships in a series to incorporate updated specifications to the degree they presently do. Skepticism is

expressed that the large number of high cost changes, with their large risks of incompatible specifications and long time lags, have corresponding benefits.[1]

Fourth, the Navy contract is accompanied by on-site and off-site management and inspection teams acting on behalf of the customer. While their functions are facilitating in many respects, inevitably conflicts arise with performance, lines of authority and responsibility and contract interpretations of the yards. This dual management is also charged with overseeing the delivery and performance of GFE, which is thereby removed from control of the yard. Late deliveries, inoperable components, unnecessarily exact specifications, conflicting or obsolescent specifications, and inability of the yards to discipline suppliers have been frequent complaints of shipbuilders.

Lastly, the Navy ship is a durable product, typically remaining in service 20 or more years. Its replacement can be delayed for lengthy periods by extended service life treatment, conversion, or extensive repair. In a sense, therefore, the ship produced one or even two decades before competes with new demand to the latter's detriment.

b. Merchant Ship Construction

Merchant ships share with their naval counterparts some of the features that are unattractive to their producers, but possess some unique undesirable characteristics as well. They are durable and are typically tailor-made to meet the desires of the shippers who order them. Their demand is derived from the narrowly based demand for ocean-going transport services by American shippers. Durability and their essential capital-goods nature assure that the cyclicity displayed by shipping demand will be transmitted to shipbuilding demand with enhanced amplitudes. Since 1970 MARAD has been encouraging the yards to

[1]See, for example, *Naval Ship Procurement Process Study*, [2], p. 192.

develop standard designs with fewer modifications so that the benefits of series production techniques can be enjoyed. The hope of MARAD is that such measures will ultimately permit domestic yards to compete successfully with foreign yards, or at least that it will be possible to reduce the construction subsidy now paid on the difference between domestic and estimated foreign cost. In the 1950s and 1960s standard tanker designs were marketed successfully. The present broader standardization program, however, has not been as successful as had been hoped in the early 1970s.

Because merchant ships are not as technologically complex or subject to specification changes as their naval counterparts, the yards have moved toward more standardized production techniques, including modularization, off-site assembly of components, and (to a more limited degree) mechanization and automation. Automation in the strict sense--full automaticity, with feeding and discharge of work pieces and self-correcting feedback mechanisms--is simply not feasible in a shipyard, except for some minor machine shopwork. Withal, therefore, the production of ships retains the characteristics of a long-term commitment of facilities to the production of a labor-intensive, complexly assembled output, retaining individualistic features and highly dependent for economic production on a tightly time-phased programming of labor skills, materials, and components. In these respects it resembles the production of an aircraft, with the notable qualification that it is not produced in substantial quantities in a standard form.

Although merchant ships are generally much less complex than naval vessels, their periods of construction are still substantial. In Table 2-12 are listed typical times for some representative commercial vessels. Building ways are typically occupied for 12 to 15 months, with outfitting taking another 5 or 6 months. Total building time then takes from 17 to 21 months. Even though such periods do not lead to increased technological

Table 2-12. TYPICAL CONSTRUCTION PERIODS FOR SELECTED MERCHANT VESSELS

(In Months)

Type	Pre-Construction	Construction			Total
	A - S[a]	S - K[a]	K - L[a]	L - D[a]	
Dry Bulker	6	6	9	6	27
Ore-Bulk-Oil	8	7	7	5	27
Tanker	5	4	7	5	21
Container	9	4	11	6	30
LASH	3 - 6	3 - 6	11	2 - 6	19 - 29

[a]A - S: Award of contract to start of construction.
S - K: Start of construction to keel laying.
K - L: Keel laying to launch.
L - D: Launch to delivery.

Source: Compiled from MARAD data.

risk in merchant vessels, nonetheless inflation and unforeseen cost impacts are given a greater chance of occurring.

c. Repair and Conversion Services

In 1979 about 200 private shipyards were listed on the Navy's Master Ship Repair List (MSRL), inclusion on which enables a yard to bid on Navy depot maintenance. Only about 10 percent were capable of performing complex overhaul work and only 3 yards were licensed for nuclear repair and overhaul.[1]

The Navy distinguishes three types of depot work, and hence the repair services of shipyards have the characteristics relevant to each type.

(1) Conversions. The conversion of a ship incorporates a major step-up in its present mission capabilities or a provision of capacity for new missions. The replacement of guns by missiles on destroyers was such an effort. While a ship is

[1]NAVSEA Memorandum.

undergoing conversion, however, it usually also is given an overhaul.

(2) Alterations. Less extensive in purpose than the conversion, alterations retain the missions of the ship but upgrade its capabilities in those missions with new equipment or configurations. They are normally done in regular scheduled overhaul periods or during conversions.

(3) Repair. These types of service are of five types:

(a) Regular overhaul. These involve general repairs and alterations.

(b) Restricted. This comprises work which is incapable of postponement until the next scheduled overhaul and without which the ship is not capable of performing its assigned mission.

(c) Scheduled restricted. This is a type of restricted repair which is programmed ahead in a yard's schedule.

(d) Technical. These repairs are performed normally at non-yard sites with no effect on the ship's capability to fully perform its mission.

(e) Emergency voyage. Repairs under emergency conditions necessary to enable a ship to continue its mission comprise this class.

In some ways, repair, alteration, and conversion work is more skilled than most construction activity and even less subject to repetitive process. Labor must be able to make unforeseeable decisions and fewer of the metal-bending skills are required. Hence, the structure and skill levels of the labor force required for these services do not coincide with those for construction.

On the other hand, the rendering of these services does not commit facilities for long periods. The average ship repair job takes up to 10 days, a major conversion (other than a carrier) from 3 to 9 months. The facilities required differ from those needed for construction: machine shops are much more important, component-assembly equipment much less. The drydock

is the dominant fixed capital needed for repair, alteration, and overhaul services, as opposed to the building way.[1]

The relevant shipyards must schedule such shorter-term activities to mesh with ship construction activities. In general, given the excess capacity that presently characterizes the industry this has presented few problems. However, in terms of surge demand, conflicts in labor and facilities demand may arise with new construction.

Despite the lesser importance volume-wise of conversion, alteration and repair activities, as revealed in Table 2-8, the importance of these services to the economic health of the industry is not to be minimized. Their rendering permits the yards in periods of underutilization to hold their core labor forces together.

There is some evidence that a disproportionate amount of the profits of the major yards in recent years has come from this account.[2] Commercial shippers are typically most anxious to get repairs done rapidly in order to keep their ship capital in service, and consequently are ready to pay high rates for rapid repair. One yard told us in an interview that profit margins on commercial repair were frequently 20 percent. On the other hand, Navy repair work did not differ much in margin from Navy construction. Some concern is also felt in the industry that as Navy ships become more complex and costly to repair, the 30 percent of value of repair and conversions that is directed by Congressional dictate to private yards will consist of fewer ships put up in drydock. Nonetheless, NAVSEA estimated that in FY 1979, the average employment in private shipyards of 26,000 men per day was generated by Navy conversions, repairs, and alterations and that this will rise to 35,000 by 1985.

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[1] D.M. MackForlist and Arthur Newman, [17], pp. 10-12.

[2] Edward M. Kaitz & Associates, [12], p. 59.

The immediate future of commercial repair work is also encouraging for the industry. Several developments promise substantial increases in demand: the servicing of the new Alaskan tanker fleet; conversion of ships destined for the prepositioning fleet; the need to alter existing ships to meet the evolving demands of ocean shipping; the energy economy trend toward replacing propulsion plants with new slow diesels; the adaptation of tankers to meet the more rigorous standards of the Port and Tanker Safety Act that becomes effective in 1981; and the enhancement of American yards' competitiveness for the repair work of foreign shippers as the dollar's exchange value falls. Commercial repair demand, therefore, offers a rare optimistic prospect to the shipbuilding industry over the next decade.

2. Demand Factors

The U.S. shipbuilding industry's sales are dominated by several factors which operate to produce a widely fluctuating workload in new construction. Both for naval and merchant types, the demand for new ships is a *derived demand* generated by the demand for ships' services from a stock of vessels. When demands for such services rise above the ability of the existing stocks of ships to supply them, a brisk rise in new orders occurs, much greater percentagewise than the rise in the demand for services. However, when demand for such services falls even slightly below the level necessary to fully employ the existing stock, new orders fall drastically. A derived demand for a product as durable as a merchant ship must therefore be expected to fluctuate widely if the "natural" forces of demand for shipping services are cyclical, as indeed they are. These cyclical forces are enhanced when some yards specialize to a degree in certain types of ships. They thereby become more susceptible to cyclical demand than the industry as a whole.

Navy demand, of course, is not directly subject to market forces, but nonetheless has proved to be quite volatile.

The Navy's Five Year Shipbuilding Program was welcomed by the shipyards when it was first introduced as a long-awaited instrument for their longer-term planning. However, in practice, it has proved to be so volatile in its movement from one year to the next that little credence is currently afforded it in the industry. The demand for Navy ships rises and falls with the changing winds of policy in as unstable a fashion as the demand for merchant ships, as often as not increasing the amplitudes of commercial ship cycles.

The durable nature of the products is complicated by the fact that ships are "lumpy" in their provision of services. Given a rise in the demand for shipping or naval services, each new ship provides a substantial fraction of the new services' demand. This characteristic renders a demand process already unstable from its derived and durable product nature even more so.

In Table 2-13 are listed both new orders and deliveries of merchant vessels and Navy ships over 1,000 gross and light displacement tons, respectively, in the period 1954-1979. In Table 2-14 the year-to-year changes in orders are converted into percentages of the preceding year's orders; that is, the absolute change from 1954 to 1955 is divided by orders in 1954 and multiplied by 100 to obtain a graphic view of demand volatility. The instability is highlighted by the graphing of the data of Table 2-14 in Figure 2-2.

One important message from these percentage movements is that Navy orders have not served to moderate the turbulence experienced by merchant ship demand. In 16 of the 23 year-to-year movements in orders, the two types of demand moved in the same direction when measured by number and in 13 of the 25 changes when displacement is used. The two years in which Navy orders were unchanged were not counted.

Table 2-13. DELIVERIES AND ORDERS OF MERCHANT AND NAVY SHIPS, PRIVATE SHIPYARDS, 1954-1979

	MERCHANT				NAVY			
	Deliveries		Orders		Deliveries		Orders	
Year	Number	Gross Tons (000's)	Number	Gross Tons (000's)	Number	Tons, Light Displacement (000's)	Number	Tons, Light Displacement (000's)
1954	38	564	7	122	13	48	26	138
1955	3	105	18	196	14	146	13	93
1956	9	126	68	1,751	9	49	22	87
1957	23	320	35	751	23	114	14	100
1958	31	573	22	176	8	24	17	78
1959	32	717	19	196	16	64	13	63
1960	25	404	23	270	12	39	19	115
1961	25	369	31	431	16	173	24	132
1962	27	391	15	174	15	76	19	99
1963	34	462	25	291	17	81	29	148
1964	15	224	18	277	21	107	39	195
1965	16	180	14	148	18	122	23	158
1966	13	161	16	244	13	74	54	246
1967	13	163	29	750	21	109	8	50
1968	24	329	23	614	16	138	15	153
1969	22	416	8	309	31	160	6	80
1970	13	370	13	580	32	106	6	132
1971	14	407	24	617	33	147	15	88
1972	19	491	48	1,551	21	95	14	86
1973	34	887	43	2,018	8	33	7	39
1974	24	684	25	1,766	9	38	16	171
1975	19	469	14	635	3	80	16	106
1976	22	756	16	339	8	70	20	91
1977	25	1,036	13	266	12	148	15	89
1978	19	1,027	30	397	14	95	25	119
1979	21	1,298	21	487	16	108	13	61

Source: Shipbuilding Council of America, [26] various issues.

Table 2-14. PERCENTAGE YEAR-TO-YEAR CHANGES IN ORDERS BASED ON PRECEDING YEAR'S VALUES, MERCHANT AND NAVY SHIPS, PRIVATE YARDS, 1954-1979

Year	Merchant		Navy	
	Number	Gross Tons (000's)	Number	Tons, Light Displacement (000's)
1954	-	-	-	-
1955	+157.1%	+ 60.7	-50.0%	-32.6%
1956	+277.8	+793.4	+69.2	-64.5
1957	- 48.5	57.1	-36.4	+14.9
1958	- 37.1	- 76.6	+21.4	-22.0
1959	- 13.6	+ 11.4	-23.5	-19.2
1960	+ 21.1	+ 37.8	+46.2	+82.5
1961	+ 34.8	+ 59.6	+26.3	+14.8
1962	- 51.6	- 59.6	-20.8	-25.0
1963	+ 66.7	+ 67.2	+52.6	+49.5
1964	- 28.0	- 48.1	+34.5	+31.8
1965	- 22.2	- 46.6	-41.0	-19.0
1966	+ 14.3	+ 64.9	+134.8	+55.7
1967	+ 81.3	+207.4	-85.2	-79.7
1968	- 20.7	- 18.1	+87.5	+206.0
1969	- 65.2	- 49.7	-60.0	-47.7
1970	+ 62.5	+ 87.7	0.0	+65.0
1971	+ 84.6	+ 63.8	+150.0	-33.3
1972	+100.0	+151.4	- 6.7	- 2.3
1973	- 10.4	+ 30.1	-50.0	-54.7
1974	- 41.9	- 12.5	+128.6	+338.5
1975	- 44.0	- 64.0	0.0	-38.0
1976	+ 14.3	- 46.6	+25.0	-14.2
1977	- 18.8	- 21.5	-25.0	- 2.2
1978	+130.8	+ 49.2	+66.7	+33.7
1979	- 30.0	+ 22.7	-48.0	-48.7

Source: Table 2-13.

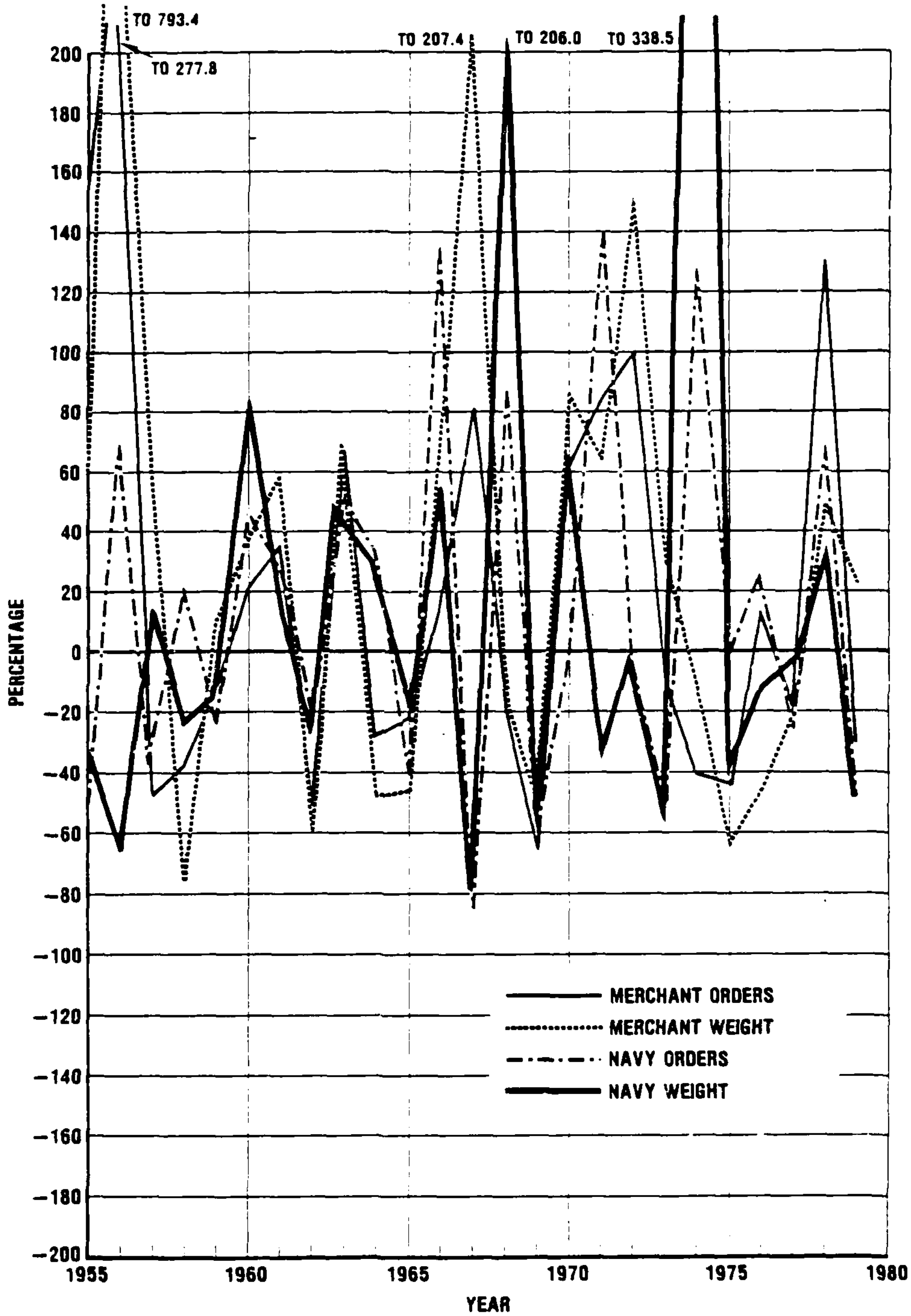

Figure 2-2. YEAR-TO-YEAR PERCENTAGE CHANGES IN ORDERS AND DISPLACEMENTS, 1954-1979

a. The Role of Government Policy in Merchant Ship Construction

Another feature of new ship demand is apparent: it is highly dependent upon government policy, both directly and indirectly. The truth of the statement for Navy ships needs no demonstration. However, the demand for merchant ships is also strongly determined by a substantial number of important government policies.

The Merchant Marine Act of 1920 (the Jones Act) reserves all domestic shipping, coastal and intercoastal, for American-built ships. Cargo preference laws require some fraction of government cargoes to move in foreign trade in U.S. ships. For example, the Military Transport Act of 1904 specifies that all U.S. armed services cargoes be moved in ships of domestic registry or construction; Public Resolution 17 of 1934 requires all Export-Import Bank-financed cargoes to move in U.S. ships; and the Cargo Preference Act of 1954 requires that at least 50 percent of all goods tonnage bought by the federal government for its own use or for foreign aid or involving its credit or guarantee be shipped in private U.S. flag vessels. Title VII of the Merchant Marine Act of 1936 as broadened by the Merchant Marine Act of 1970 provides U.S. flag shippers with an operating-differential subsidy (ODS) if they operate U.S. built vessels in essential services in foreign trade.

In addition to these indirect subsidies to the shipbuilding industry, others have been established. The Merchant Marine Act of 1970 provided U.S. fleet owners the privilege of sheltering certain funds destined for acquisition, construction, or reconstruction of ships used for domestic or foreign trade if the work is performed in U.S. shipyards. This Capital Construction Fund (CCF) constitutes a substantial fiscal support to the shipping industry, and, of course, indirectly to the yards. A final program of indirect support is Title XI financing under the

Merchant Marine Act of 1936. This program permits the financing or refinancing of American-built and registered ships by government guaranteed long term loans, permitting access by shipping companies to favorable terms in the private market. In September 1979, 403 craft were under contract receiving Title XI guarantees with a total guaranteed value of $1.586 billion.[1]

Of greatest direct support to shipbuilding, however, is the construction-differential subsidy (CDS) as established in the Merchant Marine Act of 1936 and amended in the Act of 1970. The CDS subsidizes a U.S. yard (since 1970, previously the buyer) to permit it to produce a ship at a comparable cost to that in a foreign yard. A buyer negotiates for a price with a yard, and either buyer or yard applies for the subsidy from MARAD. If approved, the Maritime Subsidy Board of MARAD determines comparable foreign cost and pays the difference (currently, up to 50 percent of the cost of the ship) as a CDS. These Title V grants are contingent upon U.S. ownership and construction of the ship for foreign operation with wholly U.S. crews, in addition to other requirements. MARAD also has a rarely-used right to direct such construction to specific yards or regions if it feels national security requires such action to preserve the construction base. In October 1979, 30 ships with a contract value of $2.013 billion were under contract or under construction at 9 yards receiving Title V subsidies.[2] Half of the ships were being built by Category I yards, two by Category II yards, 11 by Category III yards, and only one by a smaller "nonrelevant" yard.

[1]U.S. Maritime Administration, [38], page 79.

[2]*Ibid.*, p. 78.

b. The Role of Government Acquisition Policy in Navy Ship Construction

Of course, new ship construction for the Navy is, at its highest level of demand determination, a budgetary process subject to Congressional approval, with the short-term feature already mentioned. The nature of Navy acquisition policy and management, once appropriations are made, can now be considered.

Phases of Procurement Strategy. Since about 1950, when a rebuilding of the Navy began, an evolution through three rather distinctive procurement strategies is apparent.

(1) 1950-1962: Procurement-Base Preservation. During this phase the Navy subordinated competitive bid procedures to allocate major combatant ship contracts to yards with the goal of maintaining as large a mobilization potential as possible. The period, being one of rather mild inflationary pressure, with ships somewhat less complex than they were to become in later years, was almost exclusively one of fixed price contracts. During these years a large number of ships were built in a large number of yards, including naval shipyards. In Table 2-15 we display the dispersal contracting of the system.

As early as the late 1950's and especially in the last years of this phase, the workload in new construction began to be reduced somewhat; but the size of the program during these years overwhelmed the capacity of the major relevant shipyards. Although the pool of skilled labor was large in the late 1950's and early 1960's because of the recession that existed during the period, it was disappearing rapidly, and labor shortages were to become severe in the second phase.

(2) 1963-1970: Concept Formulation/Contract Definition. The McNamara era brought to Navy acquisition an innovative policy which completely reversed the ruling strategy. The

Table 2-15. PHASE I NAVY BUILDING PROGRAM, WITH SHIP TYPES AND YARDS BUILDING

Ship Type	Number Built	Yards
DE-1052	46	Todd (Seattle)
		Todd (San Pedro)
		Lockheed
		Avondale
DE-1040	10	Bethlehem-San Francisco
		Avondale
		Defoe
		Lockheed
LST-1179	20	NASSCO
		Philadelphia Naval Shipyard
CVAN	3	Newport News
SSN-637	37	Electric Boat
		Quincy
		Ingalls
		Portsmouth Naval Shipyard
		Mare Island Naval Shipyard
		Newport News
SSN-668	26	Electric Boat
		Newport News

Source: Gary Lee Kavanaugh, [15], p. 62.

deemphasis in Phase I of price competition was swept away in a new insistence on extensive benefit-cost analysis of proposed systems, competitive bids, and cost reduction. Under concept formulation/contract definition techniques, the Navy formulated the basic strategic role of a new vessel and its tactical

requirements, but a design competition among the yards was held to determine contract award. The goal was to reduce costs and future claims for cost adjustments by permitting the successful bidder to design the vessel, with the assurance that a multiple ship contract permitting the use of series production techniques would be forthcoming. Hence, yards could confidently expand and modernize their capital bases and look forward to experiencing progress curve economies.

The extremely cost-conscious program contained the core notion of total package procurement (TPP) by competitive bidding, which threw upon the yards the responsibility and risks of design, accurate cost estimation, the acquisition of most on-board systems, repair parts, and support facilities, and even crew training. Implicit also was the hope of standardizing components for a series to the extent that non-standardization arose from granting follow-ship contracts to different yards under previous procedures.

Four contracts were awarded under TPP during the period: three nonnuclear programs (the ill-fated FDL, LHA-1 (5 ships), and DD-963 (30 ships)) went to one yard, Litton, while Newport News received the contract for the DLGN-38 (4 ships). The narrowness of the production base was implicit in the acquisition strategy, and led some yards to opt out or threaten to opt out of naval construction. Huge investments of time and money were required by the yards to join the bidding process, and the intense competition for high stakes led to buy-in bids and severely reduced profit margins.

After submitting a bid, yards had to keep their building positions open for a potential contract that usually did not materialize, with consequent loss of jobs and profit opportunities. Moreover, new production methods and series production did not yield the expected cost savings. As the Vietnam War progressed the slack disappeared from the economy, and inflationary cost escalation, much of which was not captured by

contract provisions or was not compensatable under government contract law, plagued the yards. Together with the low profit margins and the increasing adversary relationship that developed between them and the Navy, these cost disturbances and disappointments set the stage for huge claims against the Navy. In the spring on 1970, CF/CD and its companion, TPP, were abandoned.

(3) 1970 - present: Competitive Negotiation. The year 1970 saw both the commitment to a 600-ship Navy and the passage of the Merchant Marine Act of 1970 with its extension to the yards of construction subsidies. From 1971-1976 fully 88 new ship contracts were placed by the Navy which, while below the huge levels of the 1960s, were imposed on industry order books for merchant ships that were largely in response to the 1970 Act, yielding a busy industry in the first half of the decade.

Competitive negotiation for a single year's acquisitions, with some return to subordination of cost as a sole basis of contract award, characterized acquisition policy. The award of the FRG contract in 1973 set the pattern for acquisition that continues presently. The contract for the lead ship is awarded under a cost-plus-incentive-fee (CPIF) arrangement. After several years pass and the design stabilizes, follow-ships are contracted for under fixed-price incentive (FPI) provisions. Ordinarily, although the Navy signs contracts only for the relevant year's procurement, it takes options to buy additional ships in the years ahead, which it has usually exercised. These competitive negotiation awards were used for the DDG-47, LSD-41, and the MCM, and for the latter two contracts the lead ship contractor was permitted to participate in the design and drawings preparation.

The new policy has certainly not completely eliminated the difficulties of the Navy procurement process, but, with the settlement in the late 1970s of most outstanding claims and a greater understanding of the yards' problems by the Navy in

recent years a great deal of the disgruntlement of management has disappeared. A large portion of the resentment of the yards in the mid-1970's originated in the belief that the Navy, as a monopsonistic buyer, forced profit margins down to unreasonable levels. They felt that the structure of the budgeting and contracting process produced career incentives which caused Navy contract negotiators to lose sight of the long-run need to preserve the acquisition base by permitting the industry to earn necessary profits. These short-sighted incentives exploited an industry that was frequently seeking orders out of desperation in the need to hold its labor force until the next cyclical upturn. In our interviews with yard managements and in the literature less such criticism was encountered, leading to the belief that some changes have occurred in Navy attitudes. The problems that remain in the cost analysis shall be reviewed.

3. Supply Factors

On the supply side, five factors are important in characterizing the industry. The first is the dominance of skilled labor in the cost structure combined with an initially surprising lack of learning economies as reflected in progress curves. A second feature is the strong role of uncertainty of price and cost movements in the supply of a product whose period of production may be 2 to 6 years, and the role of the government in allocating that risk between itself and the yards. Finally, three factors are potentially output-limiting in periods of surge demand: labor skills, building ways and associated facilities, and some materials and components. Each of these factors are examined in this section.

a. Costs and the Progress Curve

Tables 2-4 and 2-5 show that, for both naval and merchant vessels, materials are a large element of costs of construction. This importance is tempered somewhat when all shipyard activities

including repair are taken into account. In Table 2-16, for convenience, Table 2-4's data on cost of materials for shipbuilding and a sample of comparable industries are repeated. Shipbuilding's percentage is there seen to be the next to lowest. Unfortunately these data are distorted because, as Table 2-8 revealed, ship repair makes up about 24 percent of the industry's primary product. It is intensely labor-using, with 80 percent of costs accruing to labor and overhead versus 40 to 60 percent in new construction. The comparison industries do not contain this substantial services sector.

Nonetheless, even when discounted by these considerations, labor cost in ship construction is substantial. The strength of the labor cost component can be seen in contrast in the data of Table 2-17. As a percentage of value added by the yards, the shipbuilding industry's labor is a leader by a large amount, fully 65 percent being accounted for by payroll costs. Part of this is explained by the highly skilled nature of the labor force: production workers, for example, at 79 percent of the labor force, dominate total employees to the highest degree for the seven industries listed. Yet hourly earnings of production workers are among the lowest, as is payroll per employee. Average hourly earnings data reflect the low profitability of the industry and the fact that shipyard craft unions are not, in general, as powerful or aggressive as those in most of the industries listed. But production labor in shipbuilding generally does not have at its disposal the large amounts of capital available to the other industries, nor is the product as susceptible to mass production as most of the other industries'. These facts are implied by the quite low value added per shipyard employee and per production worker hour in Table 2-17; their obverse is high labor costs per unit of output.

On a more detailed basis, the distribution of value added in merchant ship construction is shown for a sample of typical vessels in Table 2-18. When engineering costs--which are largely

Table 2-16. COST OF MATERIALS AS PERCENTAGE OF VALUE OF SHIPMENTS, 1977, FOR SHIPBUILDING AND COMPARABLE INDUSTRIES

Industry		Materials Cost as Percentage of Value of Shipments
3731	Shipbuilding and repairing	41%
3312	Blast furnaces and steel mills	63
3441	Fabricated structural metals	54
3494	Valves and pipe fittings	42
3531	Construction machinery	54
3541	Machine Tools, metal cutting	37
3711	Motor vehicles and car bodies	73
3721	Aircraft	45
37	Transportation equipment	58
	All manufacturing establishments	57

Source: U.S. Bureau of the Census, [32].

Table 2-17. VARIOUS INDICES OF LABOR COST IN SHIPBUILDING AND COMPARABLE INDUSTRIES, 1977

Index	Industry (SIC Code)						
	3731	3312	3441	3494	3531	3541	3721
1. Payroll/Employee	$14,136	$19745	$13,228	$13,495	$16,398	$15,981	$17,853
2. Production Workers as Percent of Total Employees	79 79	79 79	73 73	69 69	71 71	73 73	53 53
3. Average Hourly Earnings of Production Workers	$6.52 $6.52	$9.94	$5.80	$6.08	$8.02	$7.08	$7.59
4. Value Added/ Employee	$21,681	$34,694	$25,777	$31,141	$36,986	$31,423	$36,525
5. Payroll as Percent of Value Added	65 65	56	51	43	44	50	49
6. Value Added/Production Worker Hour	$13.80	$22.92	$17.75	$22.63	$27.00	$24.45	$34.96

Source: U.S. Bureau of the Census, [32].

Table 2-18. PERCENTAGE STRUCTURE OF VALUE ADDED FOR TYPICAL MERCHANT VESSELS

Category	C-4 Cargo	C-8 Barge Carrier	Ore-Bulk-Oil 80,000 DWT	RO/RO 18,000 DWT	Tanker 86,000 DWT	Container	LASH
1. Labor	41.3	38.9	46.2	47.0	55.9	48.8	46.6
Hull	19.6	19.3	21.0	19.5	23.5	24.8	18.7
Outfit	16.3	15.0	10.5	13.0	16.6	17.5	14 3
Machinery	5.4	4.6	4.0	4.0	3.2	6.5	4.0
Other	-	-	10.7	10.5	12.6	-	9.6
2. Overhead, Including Profit	35.7	39.1					
3. Indirect Costs	9.4	9.0	53.8	53.0	44.1	51.2	53 4
4. Engineering	13.6	13.0					
5. Total	100.0	100.0	100.0	100.0	100.0	100.0	100 0

Source: Lester B. Knight and Associates, [16], Volume II, pp. 108-113.

labor--are added to the labor category in Table 2-18, labor costs seem in most cases likely to be well in excess of 50 percent of value added.

Production workers, or, broadly, those workers directly involved with the physical production of ships and repair services, are a large percentage of the total labor force, as is clear in Table 2-17, line 2. In composition, this type of labor is dominated by 10 critical skills, which comprise about 65 percent of the production workers. They are:

1. Shipfitters
2. Riggers
3. Loftsmen
4. Welders and flamecutters
5. Machinists
6. Electricians
7. Pipefitters
8. Sheetmetal workers
9. Boilermakers
10. Electronics mechanics.

Only the first three categories are unique to shipbuilding: the other seven are skills that are in general use in American industry. Recent estimates of the distribution of six of the seven shared labor types among shipbuilding, construction, and all other industries are given in Table 2-19.

Two characteristics are apparent from that display. First, the shipbuilding industry employs minor fractions of the total national employment of these skills, with the exception of boilermakers. Hence, in periods of surge demand for new ship construction, it should be able to draw readily from uses in other sectors of the economy. Labor supplies should be rather elastic, except when demands for the products of industries competing for labor are rising equally rapidly. Second, the construction industry is the major potential source for 3 of the 6 categories in periods of surge demand, and an important potential source for 2 of the remaining 3. It is, then, that industry which is most directly in competition with the shipyards for labor.

Table 2-19. ESTIMATES OF THE DISTRIBUTION OF SIX SKILLS BY INDUSTRY GROUP, 1980

Occupation	Shipbuilding	Construction	All Other
1. Welders and flamecutters	5.7	10.5	83.8
2. Machinists	4.5	1.2	94.3
3. Electricians	2.66	44.9	52.5
4. Pipefitters	3.8	57.8	38.4
5. Sheet metal workers	3.7	32.3	58.0
6. Boilermakers	8.6	15.8	75.6

Source: Neil S. Weiner, *et al.*, [47], p. 35.

That competition is an unequal one in most respects. Shipyards pay less for the same skills than construction does, and frequently require the laborer to work in dirtier, more cramped, and noisier conditions. On the other hand, they offer the worker more stable employment and a fixed location. Nonetheless, in periods of prosperity for construction, shipyards tend to experience a rapid rise in turnover, especially among younger workers. Recent experience in weekly earnings, hours worked, and hourly earnings in construction and shipbuilding are displayed in Table 2-20, and it evidences the lower wages but greater stability of hours worked obtainable in the shipyards.

These data do much to explain the large rates of labor turnover in shipbuilding, defined as the sum of labor force accessions and separations during a period of time. These rates will be discussed in more detail when the industry's labor usage is discussed. The implication of the turnover rates of relevance here, however, is a high cost of labor education which springs from the need of the shipyards to pay to educate labor lost to other industries. Hourly and weekly earnings are significantly lower in shipbuilding than in such

Table 2-20. PRODUCTION WORKER WEEKLY EARNINGS, HOURS WORKED, AND HOURLY EARNINGS PER WEEK IN SHIPBUILDING AND CONTRACT CONSTRUCTION, 1970-1980

Year	Weekly Earnings		Hours Worked		Hourly Earnings	
	Contract Construction	Shipbuilding	Contract Construction	Shipbuilding	Contract Construction	Shipbuilding
1980	385.44	346.18	37.9	40.3	10.17	8.59
1979	361.76	302.33	38.0	38.5	9.52	7.85
1978	324.85	282.27	36.5	39.7	8.90	7.11
1977	298.19	257.68	36.1	39.4	8.26	6.54
1976	284.56	247.33	37.1	39.7	7.67	6.23
1975	265.35	217.09	36.6	39.4	7.25	5.51
1974	299.68	189.74	38.9	38.1	6.75	4.98
1973	235.69	178.41	37.0	38.7	6.37	4.61
1972	221.51	172.66	36.9	39.6	6.03	4.36
1971	211.67	162.74	37.2	39.5	5.69	4.12
1970	195.45	158.00	37.3	39.9	5.24	3.96

Source: U.S. Department of Labor [42], various issues.

representative alternative employments and high rates of turnover are the result.

Most recently labor costs have taken a large step forward with the inclusion of shipyard workers in federal workmen's compensation regimes rather than state. In November 1972, amendments were made by Congress to the Longshoremens' and Harbor Workers' Compensation Act to broaden its coverage to include all shipyard and other workers laboring dockside both on and off vessels being built, repaired, or serviced. The effects upon payroll cost have been dramatic and will become worse as insurance rates rise. One Shipbuilders Council of America research paper asserts that in the next decade workmens' compensation costs will rise at 6 times the rate of payroll rise. The large rise in benefits paid has also led to malingering and is becoming a significant productivity impediment.

The major role of labor costs in total costs, especially where such a large proportion of the labor force is skilled or semi-skilled, leads to the expectation that steep progress curves for cumulative outputs in the same ship series would be experienced, for the hope of learning economies is based on labor usage. However, progress curves for commercial ships are quite shallow for the industry and of doubtful relevance for Navy ships.

Conventional progress curve theory asserts that good empirical fits of the cost of cumulative units of output are obtained from the formula

$$C_X = C_1 X^{\alpha} ,$$

where C_1 is the cost of the first unit built, X is the position of the unit in the series, C_X is the cost of that Xth unit in the series, and α is a constant obtained from the data. Progress curves are simply characterized by the amount of decline in the unit costs when output doubles. By the construction of the formula above, the percentage that the cost of the second unit bears to the first, the fourth to the second, the eighth to the fourth, etc., is constant, and is derived by raising 2 to the α power and multiplying by 100. Thus, for example, if $2^{\alpha} \times 100 = 95$ percent, the cost of the 2Xth unit in a cumulative output will fall to 95 percent of the cost of the Xth unit. The smaller this percentage value is, of course, the greater are the cost reductions springing from the progress phenomenon.

Our prior studies of merchant ship production in 1977 for 5 ship types in 4 large yards yielded 91 to 98 percent curves, with a clustering in the 95 to 97 percent area. These findings were reinforced by testimony of shipyard executives before Congressional committees, by the study of the Commission on American Shipbuilding, and in a report by the Webb Institute.[1]

[1]For a presentation of this analysis in greater detail and a listing of the references stated above, see John D. Morgan, *et al.*, [21], pp. 65-68.

Several implications can be drawn from the prevalence of such cost conditions. First, because all important economies in absolute terms are exhausted by the 8th or 9th unit in the series, shipowners forego few economies by dividing purchases among yards or by purchasing smaller batches of a ship type over a multi-year period. Indeed, in inflationary periods, spreading orders over several yards results in large savings at little sacrifice of series economies. Secondly, the empirical evidence casts some doubt upon the effectiveness of capital investment or technologies in shipbuilding that are based on series production.

The causes that underlie the shallow progress curves of merchant ship production--essentially, the need to treat each new ship in a series as a production effort independently of the previous unit and the desire to introduce design changes into the ships over the long construction periods--are even more pronounced in Navy shipbuilding. Construction periods are longer, naval warfare weaponry and support systems undergo rapid changes, and each unit has a complexity that is not approached by merchant vessels. For these reasons each ship in a series is in a very real sense a different product, and the opportunities for progress curve economies disappear with the need to introduce new technology. These characteristics make the progress curve for naval vessels inappropriate: movements from unit cost to unit cost as a series progresses are best interpreted as individual points on progress curves that are shifting upward due to enhanced complexity.

Most declines in unit cost that do occur in shipbuilding are due to the spreading of certain types of fixed costs over units and to a smaller degree to discounts on supplies and components that series production permits. Design costs of a new ship are substantial and often more important than the costs of fixed capital in an industry that is not highly

capitalized and in which much of the fixed capital has already been amortized. Also, because marine usage is such a small portion of a typical suppliers' output, volume discounts are limited as a source of economies.

In real terms, therefore--before taking into account the additional complications of inflation in an industry with peculiarly long production periods for its products--sharply declining unit costs are not experienced, and such reductions as do occur are in large part ascribable to the rather arbitrary methods of spreading sunk design costs which differ from firm to firm.

b. The Role of Uncertainty in Costing

Realistically, from the viewpoints of company profitability and of government budgeting, declining real costs that spring from the considerations discussed are swamped by cost increments which, if not unique to shipbuilding, are peculiarly severe in it. These costs are inherent in the uncertainties that surround the construction over a long period of a labor/cost-intensive product certain to undergo design and construction changes with cost impositions that are all but impossible to trace.

Uncertainty costs are peculiarly endemic to Navy shipbuilding because of 1) the very long periods of construction involved; 2) the technological complexity and rigorous specifications of the products; 3) the frequency of changes dictated by technical developments or strategic and tactical requirements; and 4) the rigorous scheduling and time-phasing of materials and components involved, many of them untested and with minimum production experience. To these, perhaps, should be added the peculiar rigidities of the legal frameworks and institutions within which government contractors are forced to confront cost uncertainty and its impacts.

An important element in the shipbuilding industry's cost structure, therefore, is the manner in which uncertainty costs are effectively allocated between yard and Navy. The principle is clear and agreed-upon: the yards should bear the burden of unforeseen costs for which their actions or lack of action are responsible, the Navy should bear the costs of those for which it is responsible, and those beyond the control of both parties should be shared in some agreed manner that places no premium upon shipyards' relaxation of vigilance or cost-consciousness. Because so much of the antagonism between the yards and the Navy arises in this area of uncertainty in cost allocation and the health of the industry is so dependent on such allocations, some of the major areas of contention are detailed below.

(1) Cost Escalation Through Inflation

Inflation was relatively mild and foreseeable in the post-war period prior to the middle 1960's. However, with the Viet-nam War and OPEC this changed abruptly and well designed esca-lation clauses became important to make fixed-price contracts practicable. There seems little doubt that the yards' pressing of claims against the Navy in the late 1960's and 1970's was intensified by their desire to recoup uncompensated losses to inflation inflicted by fixed-price contracts signed during the period of total package procurement.

A difficulty in any such indexing procedure is to adopt a measure of cost escalation that tracks sufficiently closely the inflationary experience of producers in different regions pro-ducing different ship types with different factor and materials' structures. Prior to fiscal year 1976 the Navy used rather broad indices for inflation with very little specificity to shipbuilding. It was strongly criticized by the industry. In that fiscal year NAVSEA adopted a more specific index which is acknowledged by the industry to track costs more closely but is still criticized--perhaps inescapably, given the diversity

of conditions it must face. West Coast yards especially, in interviews with IDA, were critical of the inability of the labor cost index to track their regional wage escalation.

Some experimentation with permitting shipbuilders to adopt or construct their own inflation indices in their contracts is going on at the present time although most efforts in this direction have been disallowed. As inflation remains at double-digit levels or intensifies, it is expected that greater use of regional product specific escalation indices will become more common.

(2) Technical Risk

Abstracting in what follows from inflationary uncertainties, the analysis now turns to three types of "real" cost incertitudes--technical, estimation, and scheduling--and the limitations of the frameworks within which these costs must be assessed and allocated. By "technical risk" is meant the complex of cost uncertainties that spring from the inability of the yards or the Navy to foresee future technological advances, to assess fully the production implications of design specifications required by the ship concept desired, to judge the capability of GFE suppliers to design and produce the complex products promised, and, through the sheer size of the initial design task and that of foreseeing all design modification interactions, to dispel the uncertainty that surrounds the costing of the production proce. or constructive changes in it.

In principle, under the Armed Services Procurement Regulations (ASPR), the Navy accepts responsibility for costs incurred for most nonforeseeable modifications that cause so much of this uncertainty. A Suspension-of-Work Clause also provides a price adjustment when the Navy orders work suspended or delayed to cope with technical uncertainty. In practice, disagreements often occur. A large literature exists concerning claims arising under such regulations, and this study does not propose to

review it.[1] Although the Navy in recent years has made special efforts to mitigate many of the causes of shipbuilders' concerns, there still exists some feeling in the industry that the Navy has sought to shift the costs of uncertainties onto the yards to an unwarranted degree by specific provisions (e.g., contract clauses denying the yards entitlements for the costs of constructive changes incurred more than 20 days before such changes are identified and reported to the Navy) or by effective procedures.

Some of the major complaints by the yards against Navy management on these accounts are the following:

(1) Navy design specifications are often inadequate;

(2) unexpected increases in quality assurance standards are imposed without cost adjustment;

(3) ambiguously authorized verbal constructive change orders are given by Navy management with consequent uncertainty of or delay in cost payments;

(4) the receipt of defective GFE whose consequent costs of adjustment are inflicted on the shipyard;

(5) late or inaccurate lead-ship yard working plans which place unexpected costs on the follow-ship yards; and

(6) the provision of inadequate time to study technical requirements before bidding on contracts.

The structure of Navy management and its specific impacts on the costs of technical uncertainties are discussed below.

(3) Estimation Uncertainty

A universally accepted fact by industry and the Navy is that cost estimation, both *ex ante facto* and *ex post facto*, is very difficult in naval construction. One of the major instances of this difficulty is in the costing of Navy-authorized constructive change orders. Such orders lead to rip-out or damage to completed work, uncertain impacts upon unchanged work, a disruption of labor and consequent delay to other

[1]See, for example, *Naval Ship Procurement Process Study*, [2].

projects, disputes over the assessment of blame for the changes, huge investments of personnel time in preparing the paperwork for cost claims, and the incurring of costs that are not recompensable under ASPRs. Moreover, in this area more than any other, industry officials are most critical of Navy management. It will be useful, therefore, to describe the outlines of that management before indicating where criticism is incurred.

Most of the responsiblity for new ship acquisition lies in NAVSEA. Four directorates or divisions of NAVSEA are directly involved in new construction and are intimately involved with the shipbuilding industry:

(1) Naval Ship Engineering Center (NAVSEC). It develops contract designs and specifications for ships and serves as a technical advisor on design changes and GFE.

(2) Contracts Directorate (NAVSEA 02). Construction contracts can be entered into only by its procurement contracting officers. It is prominent in the negotiation of new contracts and in claims adjustments for constructive changes.

(3) Ship Acquisition Project Managers (SHAPMs). After the contract designs and specifications are completed by NAVSEC and contracts are let by NAVSEA 02, direct responsibility for oversight of the program is assumed, across participating shipyards, by a project manager. Through ship project directives, such managers oversee project funds and provide information, services, and GFE to fulfill the Navy's responsibilities under the contracts.

(4) Supervisors of Shipbuilding (SUPSHIPS) are NAVSEA's direct contacts with the shipyards located either at the participating yards or in their geographical vicinity.

Basically, SHAPM and SUPSHIPS responsibilities are defined project-wise across shipyards in the first case and shipyard-wise across projects in the second. On the face of it the system seems ideally designed to lead to conflicts of responsibility and decisionmaking, but in practice all of the yards interviewed but one expressed satisfaction with the SHAPM/SUPSHIPS structure.

This confirmed the evidence gathered by other investigators.[1] The smooth functioning of the system, however, is vitally dependent upon the quality and experience of the Navy personnel assigned within it, and the yards did express some concern that uninterested or unsuited occupants might disturb the functioning of the system.

A certain amount of flexibility seems to be present in cost estimating and claims submission under current arrangements. Some yards, for example, settle each cost of a constructive change incrementally with the resident SUPSHIPS representative, others find that combining them in batches works equally well. In interviews with shipyard management a definite impression registered that in the last three or four years both sides have become more pliable, and that NAVSEA most particularly has tried to give its on-the-scene management representatives more authority and encouragement to negotiate. Only one yard management interviewed felt that the adversary relationship of the claims heyday in the mid-1970's persisted with no perceptible improvement.

Major criticism leveled by industry management at NAVSEA administration focusses upon NAVSEC and, most especially, the Contracts Directorate. NAVSEC's perceived failure to deliver consistent designs and specifications on time is tempered by a sympathetic understanding arising from shared industry experience with the current shortage of naval architects and engineers. So strained is their supply that some managements spoke of importing foreign talent under temporary work permits.

Less understanding was displayed with the Contracts Directorate's hiring ceiling and reduction of personnel by attrition over the last 10 or 12 years. The universal opinion was that knowledgeable civil service hands, many of whom had industry experience and who understood problems immediately and settled

[1]See, for example, *ibid.*

cost disputes quickly, had disappeared. More Navy personnel without long term experience or career interests in shipbuilding were felt to be active in contracts negotiation; their professional incentives were perceived to lead them to drive industry cost claims or profit margins to minimum levels. Long delays are felt to be frequent in contract negotiation and claims adjustments, with increased costs in yard management time, clerical overhead, and time slippage.

One of the most important manners in which the yards feel that the Navy seeks to place the onus of cost increases supposedly within the yards' control upon their shoulders is through the use of fixed-price contracting, usually with incentives for efficient performance. Various recent study groups have recommended that cost-type contracts be used for lead ships and fixed-price incentive contracts be employed for follow ships.[1] Most recently, the Naval Ship Procurement Process Study Group,[2] whose purpose was to recommend changes in new ship acquisition that promised to reduce the volume of claims in the future, recommended that lead ships and early follow ships in a series be done on cost-type contracts in the lead-ship yard until design had settled down into relative stability, and that fixed price plus incentive fee be used for subsequent follow ships.

Industry reaction was dichotomous on the question of cost-type versus fixed-price contracts, confirming earlier studies. Yards that built amphibious/auxiliary or smaller combatant types in large series felt that fixed-price contracts after the lead ship and one or two follow ships were quite acceptable and conformant to good free enterprise practice. Those yards producing larger combatants or complex ships questioned whether fixed-price contracts had a role in the industry, given that

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[1] Reference [21], pages 227-229.

[2] Reference [2].

every follow ship tended to be different from its predecessors. Those opposing fixed-price contracts felt that through its use the Navy unjustly sought to saddle the industry with the burdens of cost estimation uncertainty that were largely beyond the yards' ability to anticipate.

(4) Schedule Uncertainty

A last type of uncertainty with cost implications is that which results in slippage from scheduled performance dates. Some evidence exists that Navy planning factors, although they have become more realistic in recent years, are still optimistic. For example, the Naval Ship Procurement Process Study Group found that Navy-projected time-phased rates of labor application for its new construction were not achieved by the yards.[1] Much industry concern centers about the long lead times for many components, and the inability to order ahead in the absence of multi-year contracting. Slippage in such deliveries is not in control of the yards. Moreover, GFE is often delivered late or in unsatisfactory condition, leading to schedule delays. The J-22 clause, which sought to limit the Navy's responsibility for late delivery of GFE, was a complaint of larger yards. Yards producing smaller ships with well-established supply channels for GFE experienced no problems with it.

c. Labor Supply and Usage

In the discussion of labor costs above, several points were made about the nature of labor usage in shipbuilding. In Chapter IV, when the adequacy of specific labor skills to support the four shipbuilding programs comes under analysis, the study becomes more specific in terms of regional and craft supply. At this point in the economic financial overview, the study remains rather macroscopic.

[1] *Ibid.*, pp. 73 ff.

Shipbuilding labor is craft-delineated, predominantly unionized, in largest part skilled or semi-skilled and, with few exceptions (shipfitters, riggers, and loftsmen), closely akin in its skills to requirements in industries that compete for its supply.

On the horizon various features of shipbuilding technology could alter this characterization, although drastic changes in the next 10 years are not foreseen. Cost reduction motives are leading the yards to accelerate modular construction techniques, to introduce more numerical control machinery, to use downhand welding, to standardize major ships' parts, to move to product specialization within yards to the extent an unstable workload permits, and to the purchase of supplies instead of on-site production. Such promising procedures as increased use of computer graphics for design and lofting, laser alignment and welding, and robotization also will be adoptable by the shipyards of the near future. Each of these tendencies should lessen the yards' needs for production workers, and will reduce the skilled craft bases of shipyard labor. That labor will be trained more quickly and cheaply and will be able to be expanded more rapidly in a mobilization or surge demand period.[1]

However, it is doubtful if such potential trends will cause drastic labor force changes within the 10-year horizon. Naval ship construction, with its greater complexity, may place stricter limits upon such technological innovations that apply primarily to commercial ship construction. Widespread adoption of the new techniques implies the substitution of large capital outlays for those on labor, limiting the ability of the yards to tailor costs to levels of demand by adjusting the size of the labor force. This flexibility has been highly prized by the industry in the past, and has been a factor in delaying such innovative methods. Lack of workload stabilization should

[1] National Research Council, [22].

continue to limit the willingness of management to invest too heavily in such capital improvement. Lastly, the profitability of the industry is not such as to lead multi-profit center owners to make such investments, especially because the industry exists largely by the largess of national policy in spite of its noneconomic nature; hence, state-of-the-art technology to guarantee survival will not be as crucial as in other industries.

The analysis assumes that the balance of skills needed in shipbuilding for the next 10 years will be close to that displayed in Table 2-21 (which was derived from a MARAD sample from Category I yards about 1974) with perhaps a somewhat greater role accorded electronics mechanics at the expense of other skills.

Table 2-21. DISTRIBUTION OVER MAJOR SKILLS OF TOTAL WORKERS IN CATEGORY I SHIPYARDS (c. 1974)

Skill	Percentage of Production Workers
1. Shipfitters	10.0
2. Riggers	4.4
3. Loftsmen	.8
4. Welders and flamecutters	18.6
5. Machinists	8.1
6. Electricians	7.1
7. Pipefitters	6.2
8. Sheetmetal workers	3.9
9. Boilermakers	.5
10. Electronics mechanics	.4
11. All other production workers	24.1
12. Non-Production workers	15.9
TOTAL	100.0

Source: MARAD, as quoted in National Academy of Sciences [22], p. 74.

As indicated in Table 2-19, for the six skills which are not specific to shipbuilding, the industry's demand is, on a nationwide basis, a small fraction of available labor force, being in five cases under six percent and in all cases under nine percent. On the face of it, supplies of such labor should be relatively elastic overall. However, as noted, high turnover rates, especially among young workers, characterize the industry, and that experience must be investigated to note its importance as a symptom of supply problems.

First, evidence exists that as great as the turnover is, it is not a great deal higher than that for other industries employing similar skills. Table 2-22 presents the longer-term data on turnover which have been located (somewhat dated though they are). These data are extracted from a scholarly study completed in 1978, so that nonexistence of extensive later data on other than a partial or fragmental basis seems confirmed. From the table is seen that in 1965 (1970) the percentage of male workers who were in shipbuilding but were not so employed in 1960 (1965) was about 43 (57) percent. The percentage of male workers in shipbuilding in 1960 (1965) but not so employed in 1965 (1970) was about 47 (54) percent. In absolute terms these data indicate large turnovers, but relative to other industries in the sample the experience does not seem unusual. Most significantly, construction reveals a similar pattern.

If the average of the separation and accession rates for the later period 1965-1970 is used as an index of longer-term turnover in a period of full employment for the economy as a whole, the data of Table 2-23 are derived. Although shipbuilding suffers from a quite high long-term turnover rate, it is seen once more that it does not differ a great deal from those in construction or other types of transportation equipment industries.

Table 2-22. TURNOVER RATES IN SELECTED INDUSTRIES, MALES, 1960-1965 AND 1965-1970

	Separation Rate[a]	Accession Rate[a]
<u>1960-1965</u>		
1) Construction	47.9%	54.9%
2) Manufacturing (except transportation equipment)	34.3	36.1
Motor vehicles	35.3	45.1
Aircraft	46.4	42.7
Shipbuilding	46.8	51.6
Misc. transportation equipment	59.8	71.7
3) All Industries except 1) and 2)	33.7	40.6
<u>1965-1970</u>		
1) Construction	47.8	51.9
2) Manufacturing (except transportation equipment)	35.7	41.6
Motor vehicles	42.4	43.8
Aircraft	38.7	43.5
Shipbuilding and repairing	54.0	56.5
Misc. transportation equipment	61.3	70.5
3) All Industries except 1) and 2)	34.4 34.4	44.5

[a] *Accession rate* is percentage of workers in an industry in a given year who were not in the same industry 5 years earlier. *Separation rate* is percentage of workers in an industry in a given year who were not in the same industry 5 years later.

Source: John C. Martin, [19], Table VIII.1. Based upon a continuing Social Security sample. Extended and modified by National Academy of Sciences, [22], p. 82.

Two distressing data revealed in Martin's study, however, are that separation rates in the period 1965-1970 were higher in the under 25 age group for yard workers than most industries listed in Tables 2-21 and 2-22, and that separation rates in

Table 2-23. TURNOVER INDEX VALUES DERIVED AS AVERAGES OF SEPARATION AND ACCESSION RATES, SELECTED INDUSTRIES, MALES, 1965-1970

Industries	Index
1) Construction	50.0
2) Manufacturing (except transportation equipment)	38.7
Motor vehicles	43.1
Aircraft	41.1
Shipbuilding and repairing	55.3
Miscellaneous transportation equipment	65.9
3) All Industries except 1) and 2)	39.5

Source: Table 2-22.

the 55 and over age group were also high. These data lead to the belief that the shipbuilding labor force is not only an aging one with less appeal to entry level workers than others of like work skills, but that older workers are leaving the industry before retirement age for other employment.

The possibility of an inverted wage structure, which pays young workers more than is necessary to train them and pays mature workers less than is necessary to hold them, is borne out by data on pay differentials among skill and experience categories in shipbuilding. At Electric Boat, for example, in 1974 a junior third class carpenter earned $4.34 per hour after just completing his apprenticeship, while first class carpenters who have been in the trade a number of years earned only $4.94, or less than 14 percent more! The same problem was found for electricians.[1] Nationwide across all industries, these seniority differentials were 39 to 45 percent.[2] In several yards, for example, it was found that increasing the

[1]Other aspects of the shipyard labor compensation problem are reviewed by John D. Morgan, *et. al*, [21].

[2]Sheldon E. Haber and John C. Martin, [8].

wage rate differential between first class mechanics and first level supervisors reduced supervisory turnover greatly. An illogical differential system may, therefore, play a role in the larger turnover rates in shipbuilding, but further research is necessary to determine this.

More recently short-term turnover rates for the shipbuilding industry confirm the continuance of the problem. Table 2-24 displays the monthly rates per 100 employees of accessions and separations, listing the new-hires component of the first category and quits and layoff components of the second. The high rates found in Table 2-22 seem to be worsening in this period. However, the dominant role of layoffs in separations--the curse of an industry with an unstable work load--is made clear in these data, as is the large portion of accessions made up by re-hires.

Table 2-24. MONTHLY AVERAGE ACCESSION/SEPARATION RATES, U.S. SHIPBUILDING AND REPAIR INDUSTRY, 1970-1978

(Per 100 Employees)

Year	Accession Rates		Separation Rates		
	Total	New Hires	Total	Quits	Layoffs
1978	6.8	3.2	7.1	2.2	3.7
1977	7.2	3.7	6.6	2.1	3.1
1976	6.7	3.8	6.3	2.1	3.1
1975	6.4	3.8	5.8	2.0	2.5
1974	7.4	4.9	6.5	2.6	2.2
1973	7.9	4.8	7.5	2.7	3.3
1972	8.1	3.9	7.8	2.1	4.2
1971	8.6	3.9	8.6	2.0	5.3
1970	7.4	3.7	8.1	2.2	4.6

Source: Annual Report on Status, [4].

Training periods for skilled labor in shipbuilding are quite long, at least under normal conditions, and the costs correspondingly high. Table 2-25 lists the estimated time necessary to reach first-class journeyman status in ten production jobs, as estimated by the Shipbuilders Council of America. In periods of stringency, however, the yards revert to intensive training programs to qualify workers, no doubt at some expense in skill attainment and productivity. After 12 weeks of training, for example, a welder can be assigned limited tasks in shipbuilding. Hence, in periods of surge demand or mobilization, the data of Table 2-25 would not be indicative of training necessary for qualification as shipyard production workers.

Table 2-25. SELECTED SHIPYARD PRODUCTION JOBS AND ASSOCIATED TRAINING TIMES TO QUALIFY AS FIRST-CLASS JOURNEYMEN

Job	Training Time (In Hours)
1. Welder	8,000
2. Shipfitter	8,000
3. Machinist	6,000
4. Electrician	8,000
5. Pipefitter	8,000
6. Rigger	8,000
7. Flame cutter	2,000
8. Crane operator	1,000
9. Marine draftsman	10,000
10. Shipwright	8 to 10 years

Source: National Academy of Sciences, [22].

One particularly troublesome area of labor force deficiency is that of naval architects and engineers--a deficiency which is not as readily correctible by steps that make it

possible to recruit more production workers. Three schools currently train most of these crucial professionals: The University of Michigan, Webb Institute of Naval Architecture, and MIT. Their graduates are in great demand by such government agencies as NAVSEA, by private naval design companies and by shipyards, but nonetheless it has proven to be difficult to tempt sufficient young people into an industry that most perceive to be less viable than alternative employers of their talents. If government is truly desirous of protecting the nation's procurement base for shipbuilding, a program of support for education in these crucial areas would be most advisable.

To a less crucial but nonetheless troublesome extent, it has proved difficult to tempt young management graduates into the industry. To some degree this may be the result of the industry's tendency to recruit its senior management from personnel with extensive production experience. The influx of new management following the conglomerate moves into the industry partially corrected this tendency toward inbreeding, but yards still confess their inability to compete with other industries for the ablest young management graduates.

Finally, the role of unions in the shipbuilding labor force are addressed. Although unionism has always been a factor in shipyards, given the large blue-collar and skilled trades components of their labor force, they became permanently entrenched only in World War II. They are organized along craftsmen lines, as might be expected, and in ways that are familiar in American industry which act to limit the yards' abilities to transfer workers among jobs as occasion demands. Welders cannot be used as burners, or vice versa, although the skills are quite close, nor may workers transfer between trades without loss of seniority.

Nonetheless, labor union problems have not been among the most important faced by managements. Labor relations have been quite peaceful on the whole, and the unions have recognized the

need to permit the yards a good deal of flexibility in layoffs and separations and in moving workers freely about the yards within the same skill. Union leaders have faced the restrictions set by the industry's short-run and long-run profitability difficulties in not pressing to close wage differentials for similar skills in other industries nor to seek the higher wages paid by naval shipyards. In interviews with industry management, labor union problems were not frequently mentioned as major concerns.

d. Capital Intensity and Investment in Shipbuilding

The shipbuilding industry is not one with great capital intensity: indeed, the statistical indications that are available concerning capital structure reinforce the assertion that it is a highly labor-intensive industry. This low capital usage has characterized the post war period and does not show strong signs of reversal in our most recent data.

Table 2-26 presents gross and net depreciable assets for all manufacturing, shipbuilding, and a selection of industries akin to shipbuilding in their processes for the years 1963 and 1967, before the period of increased investment in shipyards between 1967 and 1974. The figures are presented as levels and on a per employee basis. Gross depreciable assets are valued at historical costs and net depreciable assets are gross depreciable assets' net of estimated depreciation. In 1967, all manufacturing industries had gross assets of $21,644 per employee, compared with a value for the largest 31 companies in shipbuilding of only $5,878. On a gross basis, shipbuilding employees worked with only 27 percent of the fixed capital complement that the representative manufacturing worker had. On a net basis this percentage rose to only 35 percent. Moreover, these data understate the fixed capital differences for production workers in industries, since production workers tend to use

Table 2-26. FIXED CAPITAL MEASURES, 1963 AND 1967, FOR LARGE COMPANIES IN A GROUP OF MANUFACTURING INDUSTRIES

(Assets in Millions of Dollars, Ratios in Dollars)

Industry	Gross Depreciable Assets (GDA)		Net Depreciable Assets (NDA)		GDA/Employee (Dollars)		NDA/Employee (Dollars)	
	1963	1967	1963	1967	1963	1967	1963	1967
All Manufacturing	171,845	321,908	84,028	119,153	14,134	21,644	6,911	8,011
Construction	na	2,883	na	1,648	na	6,226	na	3,559
Blast Furnaces and Steel Mills	17,212	22,243	7,347	9,241	26,417	31,700	11,276	13,170
Gray Iron Foundries	437	625	194	277	11,727	11,978	5,206	5,309
Engines and Turbines	237	395	124	204	6,486	7,956	3,393	4,109
Farm Machinery and Equipment	1,091	4,213	491	2,595	9,132	24,256	4,110	14,941
Construction Machinery	609	963	311	508	9,055	10,029	4,624	5,290
Minerals and Materials Handling	432	494	189	246	7,167	7,334	3,135	3,652
Motor Vehicles and Equipment	11,503	15,906	4,807	7,397	10,922	13,346	4,564	6,207
Aircraft and Complete Guided Missiles	1,757	3,725	808	1,832	2,911	4,434	1,339	2,181
Aircraft Parts and Guided Missile Parts	1,601	3,005	710	1,424	5,571	8,564	2,471	4,058
Ships and Boats (31 Companies in 1967)	482	581	220	282	5,592	5,878	2,553	2,853

Source: U.S. Bureau of the Census, [31].

more fixed capital and the production worker to total employment ratio in shipbuilding has been shown to be quite high. Of the industries listed, only aircraft and guided missiles afforded their employees less capital per capita than shipbuilding.

In Table 2-27 the analysis is updated with gross depreciable asset data for 1975 and 1976 for selected industries. Although the absolute values for shipbuilding reflect the higher investment of 1967-1974, these latest available data indicate the same relative pattern for per employee and per production worker capital usage: capital usage ratios to labor usage are surprisingly small compared with other industries.

Investment expenditures on new capital in recent years reveal no striking tendency to upset the pattern revealed in Tables 2-26 and 2-27. Within all manufacturing industries or industries of its own ilk, shipbuilding as a whole is a laggard investor. Nonetheless, some improvement in relative position can be discerned in the investment data, although its meaningfulness in terms of improving the capital base is not easily discernible without some knowledge of the average longevity of capital assets. Because actual depreciation charges for 1967 data assumed that shipbuilding assets were about as longlived as those in all manufacturing industries, and substantially longer than those used in most of the comparison industries, Table 2-28 affords some basis for belief that at the present time the capital base of the industry is being increased and modernized to some extent.

Moreover, a study of 11 shipyards' investment over this period (Category I: Avondale, NASSCO, Litton/Ingalls, Newport News, Electric Boat, Quincy, Todd, and Bath; Category II: Sun; Category III: American, Alabama) derived from confidential company information indicates, as expected, that most of the industry's capitalization effort is going into major yards. These 11 yards' investment totals were 50 percent of the

Table 2-27. GROSS DEPRECIABLE ASSETS, AT HISTORICAL COSTS, EXCLUDING INVENTORIES, AT END OF YEAR, 1975 and 1976 (MILLIONS OF DOLLARS)

Industry	SIC[1]	1976			1975		
		GDA[2] (Millions of Dollars)	GDA Per Employee (Dollars)	GDA Per Production Worker (Dollars)	GDA (Millions of Dollars)	GDA Per Employee (Dollars)	GDA Per Production Worker (Dollars)
Shipbuilding and Repairing	3731	2,156.9	$12,968	$16,326	1,808.7	$10,838	$13,558
Aircraft	3721	2,567.5		22,073	2,458.1	11,171	20,104
Motor Vehicles and Car Bodies	3711	6,767.0	20,865	24,718	6,333.7	22,420	26,940
Machine Tools, Metal Cutting	3541	999.6	17,202	26,584	937.2	14,920	22,963
Construction Machinery	3531	3,168.1	21,876	30,971	2,662.4	17,716	24,490
Fabricated Structural Metal	3441	1,217.0	12,610	17,085	1,193.4	11,542	15,537
Blast Furnaces and Steel Mills	3312	33,645.8	74,460	93,981	30,880.5	68,421	87,042
Transportation Equipment	37	28,852.7	17,299	23,935	27,471.5	17,117	24,158

Source: U.S. Bureau of the Census, [32].

[1]Standard Industrial Code.
[2]Gross Depreciable Assets.

Table 2-28. NEW CAPITAL EXPENDITURES PER PRODUCTION WORKER AND PER EMPLOYEE, SELECTED MANUFACTURING INDUSTRIES, 1975 and 1976

Industry	SIC[1]	1976		1975	
		Per Production Worker	Per Employee	Per Production Worker	Per Employee
Shipbuilding and Repair	3731	$2,684	$2,132	$2,233	$1,785
Aircraft	3721	1,293	721	1,006	559
Motor Vehicles and Car Bodies	3711	3,824	3,228	2,789	2,321
Machine Tools Metal Cutting	3541	1,734	1,122	1,279	831
Construction Machinery	3531	4,580	3,235	3,948	2,856
Fabricated Structural Metals	3441	1,825	1,347	1,505	1,118
Blast Furnaces and Steel Mills	3312	5,984	4,741	5,829	4,582
Transportation Equipment	37	2,597	1,877	2,429	1,721

Source: U.S. Bureau of the Census, [32], and [30], 1975 and 1976.

[1]Standard Industrial Code.

industry's total ($354.6 million) in 1976 and 96 percent of that total ($297.9 million) in 1975.[1]

It is felt that increased capital investment will be made by the large yards as they innovate new technology and increase their facilities to some degree for specialization in ship construction or increase the range of ship designs for which they are capable. Certainly, as has been seen in the discussion of trends in labor usage, the possibility exists to substitute capital for skilled labor in larger yards. However, the willingness and ability to these companies to make these investments over the next 10 years will depend in large part upon a stable workload and sufficient profitability. Among the managements interviewed, an almost unanimous feeling is that excess capacity for the production of ocean-going vessels at the present levels of Navy and commercial demand exists, and that if no increase in demand occurs, some shakeout among Category I and Category II yards will occur. Moreover, profit levels are believed to be such relative to alternative uses for capital that managements would be reluctant to commit more resources to the shipbuilding base.

e. Materials and Components

Several factors have been operating in recent years that have led to large and sometimes increasing difficulties and lead times in the procurement of materials and components in the shipbuilding industry. One such burden is that shared with other defense prime contractors who encounter increased reluctance by suppliers to undertake the heavy contractual burdens and contingent liabilities imposed currently by government procurement. Shipbuilding's problems are more specifically related to the small proportions of suppliers' total sales that it absorbs, so that firms may be reluctant to tool up for production of maritime

[1]Edward M. Kaitz and Associates, [14].

items for which large volume and multi-year orders are not in prospect. Significantly, materials and component supply problems are less in evidence in yards that have been producing a large number of ships in a series that has extended over a period of years.

These difficulties have led to extremely large lead times for important materials and components, especially in years of a thriving economy. Table 2-29 presents data that reveal the trend in lead times for some of the important raw materials listed in Table 2-6. In most instances lead times have increased significantly, notably between the prosperity peaks of 1974 and early 1980. Aluminum plates, shapes, and tubing have doubled or tripled in their required lead times, in large part because of increased demand in other industries. Alloy steels also reveal some troublesome increases, and carbon steels, though displaying less growth in lead time, nonetheless are troublesome in requiring a lead time of 3 months. An especially worrisome aspect of Table 2-29 is the tendency all of these lead times reveal to increase greatly in periods of extremely high demand. This leads one to look for bottlenecks in periods of surge demand that do not occur in all-out mobilization or war.

Castings and forgings--aluminum, copper and steel--present some worrisome aspects, in almost all cases revealing lead times that are large and that escalate rapidly in prosperous periods. A sample is presented in Table 2-30.

Finally, finished ship components, in most cases, have lead times of a year to a year and a half, but they do not rise appreciably with general economic activity. Shipbuilding demand for such components as propulsion units, generators, and reduction gear are a larger portion of the manufacturers' total demand, and hence meet a more interested supply response. Table 2-31 details a sample of lead times for the more important ship components.

Table 2-29. MANUFACTURING LEAD TIMES, RAW MATERIALS, IN JANUARY OF YEAR LISTED, IN WEEKS

	1972	1973	1974	1975	1976	1977	1978	1979	1980
1. Carbon Steel									
Plate (ABS)	8	8	12	20	12	12	10	12	12
Plate (MIL)	8	8	12	20	12	12	10	12	12
Structurals (ABS)	10	10	16	24	12	14	10	12	12
Structurals (MIL)	10	10	16	24	12	16	10	12	13
2. Alloy Steel									
HY80 Plate	12	14	24	26	20	20	16	16	20
Extrusions (MIL) HY80	40	24	24	30	42	26	20	24	24
Structural Shapes HY80	12	13	24	34	24	24	20	24	26
3. Aluminum									
Plate (Heat Treatable)	16	14	24	21	12	13	12	24	36
Plate (Non-Heat Treatable)	12	11	24	21	12	13	12	24	36
Extruded Shapes (Small)	8	8	20	24	12	12	10	24	36
Extruded Shapes (Medium)	10	10	20	24	12	12	10	24	36
Extruded Shapes (Large)	16	16	24	30	12	13	12	24	42
Structural Shapes	14	14	20	26	12	13	10	24	44
Tubing	10	14	21	21	21	12	12	24	37

Source: NAVSHIPSO Memorandum, [44].

Table 2-30. CASTINGS AND FORGINGS LEAD TIMES, JANUARY OF YEAR LISTED, IN WEEKS

CASTINGS	1972	1973	1974	1975	1976	1977	1978	1979	1980
1. Alloy Steel									
Small	6	14	28	40	32	20	16	20	[illegible]
Large	24	24	36	44	36	28	24	24	24
HY (Small)	20	18	28	60	44	26	16	20	20
HY (Large)	40	30	36	70	52	36	24	28	28
2. Aluminum	10	10	12	13	10	8	10	11	11
3. Copper									
With Brass (Small)	10	10	16	20	16	12	9	9	10
With Brass (Large)	16	16	18	24	20	16	12	12	12
Base Alloys (Small)	12	12	16	20	16	12	9	12	12
Base Alloys (Large)	16	16	18	26	20	16	12	16	16
FORGINGS									
1. Alloy Steel									
Small	14	16	30	52	30	20	16	20	26
Large	20	24	44	60	40	30	20	24	40
HY (Small)	16	14	30	52	30	20	20	20	32
HY (Large)	20	28	48	70	44	36	24	26	40

Source: NAVSHIPSO Memorandum, [44].

Table 2-31. MANUFACTURING LEAD TIMES, SHIP COMPONENTS IN JANUARY OF YEAR LISTED, IN MONTHS

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Blowers									
F.D. Turbine	16	16	17	18	18	18	18	16	18
F.D. Motor	10	10	11	14	14	14	12	10	12
Boilers, Main	14	14	14	15	18	18	17	17	18
Condensers, Main	14	14	14	15	15	15	15	15	16
Distilling Plant	13	12	13	13	15	14	14	14	14
Engine, Diesel	11	11	11	11	12	11	11	12	12
Gears, Main Reduction	18	16	16	18	17	17	17	16	21
Generators									
Steam Turbine	17	18	18	20	19	19	19	19	20
Gas Turbine	18	17	17	17	18	18	18	18	18
Diesel	13	13	13	14	13	13	13	13	14
Propellers									
4' and above	10	10	10	10	11	12	11	10	11
CRP	14	13	13	14	16	16	16	16	17
SS/Swbd	17	18	18	18	17	17	17	16	16
Turbines									
Gas	17	20	20	21	21	21	20	20	22
Steam	18	18	18	20	19	19	19	19	21

Source: NAVSHIPSO Memorandum, [44].

In general, the great and growing dependence of the shipbuilding industry upon outside suppliers, the relatively small fraction of demand for many such supplies composed of maritime orders, and the large component of shipyard outfitting that is government financed and thus which subjects suppliers to government specifications, contract regulations, or scrutiny leads to large delays between orders and delivery. The importance of rather close time-phasing in shipbuilding magnifies the impacts on costs and scheduling of slippages in deliveries of supplies.

C. THE SHIPBUILDING INDUSTRY'S PERFORMANCE

The last category of industry characteristics analyzed is that relating to its performance in five important dimensions. Because some aspects of these questions have been discussed in the presentations of industry structure and conduct above, much of this information is presented compactly by refering frequently to prior discussion in what follows.

1 Sales and Backlogs

Table 2-13 presented the recent record of American shipbuilders in terms of orders for and deliveries of merchant and Navy ships. The cyclical nature of that record, which was stressed at that point of the presentation, implies that the industry has responded rather flexibly to surge demands and depressed conditions. Today there exist at least 81 building positions capable of producing ocean-going ships, which yield enough capacity to meet any anticipated demand short of mobilization or war. Some of these ways can accommodate more than one ship and in a tight pinch new building methods and multi-shift operations can effectively multiply the number of positions. Indeed, in reflection of worldwide shipbuilding's excess capacity, one must expect some of that domestic capacity

to be killed off in the next decade. Under conditions of surge demand a closer analysis of capability will be undertaken in Chapters III and IV.

The status of world shipbuilding as an industry in trouble, its peculiarly close ties to national history, the extreme dependence of certain national regions upon it for employment, and its important military position have led to its close protection and subsidization by all major nations of the world. Noneconomic production and excess capacity in technologically outmoded facilities abound. Except for cases of specialized investment or technological lead--Japanese supertankers, for example, or the United States cryogenic tankers and floating plants--export markets are attained painfully at a cost of large national subsidies.

The United States government has not been willing to pay such export subsidies, and therefore the shipbuilding industry cannot hope under foreseeable conditions for export sales. The pessimistic export scene may change, of course, if the industry invests heavily in technological knowhow to produce cryogenic tankers or specialized floating plants and if these come into strong demand.

Under normal conditions, therefore, industry sales will be dictated by Navy orders and American shippers' needs. Table 2-32 presents MARAD's current projections of merchant ship orders in the next five (fiscal) years. Broadly, it reveals very little growth in the U.S. Merchant Marine throughout the 1980's. Tankers will be built as replacements for older vessels. The Port and Safety Act will result in the construction of an unusually high number of tankers during the first half of the 1980's. The construction of dry bulkers is contingent upon the passage of legislation to increase the size of the U.S. bulk fleet. If this legislation is not passed, few, if any, bulkers can be expected to be built in U.S. shipyards.

Table 2-32. PROJECTED MERCHANT SHIPBUILDING PROGRAM, FISCAL YEARS 1981-1985, AS FORECASTED IN JANUARY, 1981

	1981	1982	1983	1984	1985
Containerships	-	-	-	5	4
Lash	-	-	1	2	-
Tankers	19	8	8	5	10
Small Breakbulk/RO/RO	1	1	1	-	3
LNG	-	3	3	3	-
Dry Bulkers	7	6	4	6	5
Great Lake Bulkers	2	5	-	1	-
Totals	29	23	17	22	22

Few bright spots in the merchant marine shipbuilding sector can be expected without additional legislation to encourage construction of merchant ships in U.S. shipyards.

Further, the Navy's Five Year Defense Plan (FYDP) reveals expectations that Navy orders will hold steady or rise gently at levels that are higher than most years in the 1970's. The FYDP is notoriously unreliable as a long-run planning tool, but with the recent change in administration and national mood, it would seem a conservative estimate of Navy orders. The FYDP is presented in Table 2-33. With conversions, Navy projections of about 20 ships per year continue the recent uptick in the Navy's shipbuilding revealed in Table 2-13. However, 17 of these ships are submarines, and three of the conversions are carriers so that 20 of the ships are restricted to specialist yards or Navy shipyards. The Aegis cruiser will also be a large ship, and hence contracts for its projected 16 units over the five years will be bid by few firms. Thus, 36 of the 102 ships will in all likelihood be preempted by Electric Boat, Newport News, Avondale, and Ingalls, leaving only 66 ships or 13 new orders on the average per year for the remaining 21 Navy relevant yards.

Table 2-33. THE NAVY FIVE YEAR DEFENSE PLAN, FISCAL YEARS 1981-1985

	Fiscal Year					
	1981	1982	1983	1984	1985	Total
1. New Construction						
Submarines						
SSBN-Trident	1	1	1	1	2	6
SSN 688	1	1	1	2	-	5
SSN-Fleet Attack	-	-	1	1	4	6
Cruiser						
CG-Aegis	2	3	3	4	4	16
Small Combatants						
DDG-X	-	-	-	-	1	1
FFG-7	4	4	3	4	-	15
NRF Corvette	-	-	1	-	4	5
MCM Mine Countermeasure	-	1	-	4	4	9
LSD	1	-	1	-	1	3
Auxiliaries						
TAGOS Ocean Surveillance	5	4	-	-	-	9
T-AK FBM Resupply	1	-	-	-	-	1
T-AKX Maritime Positioning	2	3	3	3	3	14
ARS Salvage	1	2	1	-	-	4
TOTAL NEW CONSTRUCTION	18	19	15	19	23	94
2. Conversions						
Carrier						
CV-SLEP	1	-	1	-	1	3
Small Combatants						
DDG 963 Upgrade	-	-	-	1	-	1
Auxiliaries						
T-AO	-	-	2	2	-	4
TOTAL CONVERSIONS	1	-	3	3	1	8
TOTAL NEW CONSTRUCTION PLUS CONVERSIONS	19	19	18	22	24	102

Source: Hearings, Committee on Armed Services, U.S. Senate, [45], p. 1087.

The task of testing the feasibility of shipbuilding programs will be undertaken in Chapter IV; however, in the macro terms of this chapter, an industry with 81 building positions for ocean going ships, each of which is occupied by the average Navy ship for 17 months and the average merchant ship for 12 months, should have little trouble from the viewpoint of facilities of accommodating 33 new orders per year with a weighted average building way occupancy of about 14 months. Hence, unless these program orders are added to substantial backlogs, the industry will not work to capacity in the early 1980's and should not be expected whatever these backlogs are to be fully employed in the last half of the decade.

Indeed, most yards are currently in need of new orders to maintain a sufficient backlog to employ current facilities and labor force. Figure 2-3 depicts MARAD projections in 1979 of the dates at which such new business is needed for a sample of 14 large shipyards.

It is concluded, therefore, that present and prospective new construction and conversion will not permit the 25 relevant yards to fully employ their building positions or maintain current levels of employment, with the exception of yards building specialized or large Navy combatants. No return to the low order backlogs of the mid-1970's is apparent, however, and, indeed, industry employment should not dip by a large amount if current MARAD-Navy projections materialize.

2. Investment and Technological Progress

Section B.3.d discussed the capital intensity and investment record in recent times of the industry. It was observed that the industry is not highly capitalized given the nature of the production processes. However, recent *Census of Manufactures* and *Annual Survey of Manufactures* data suggest that some intensification and modernization of the capital base

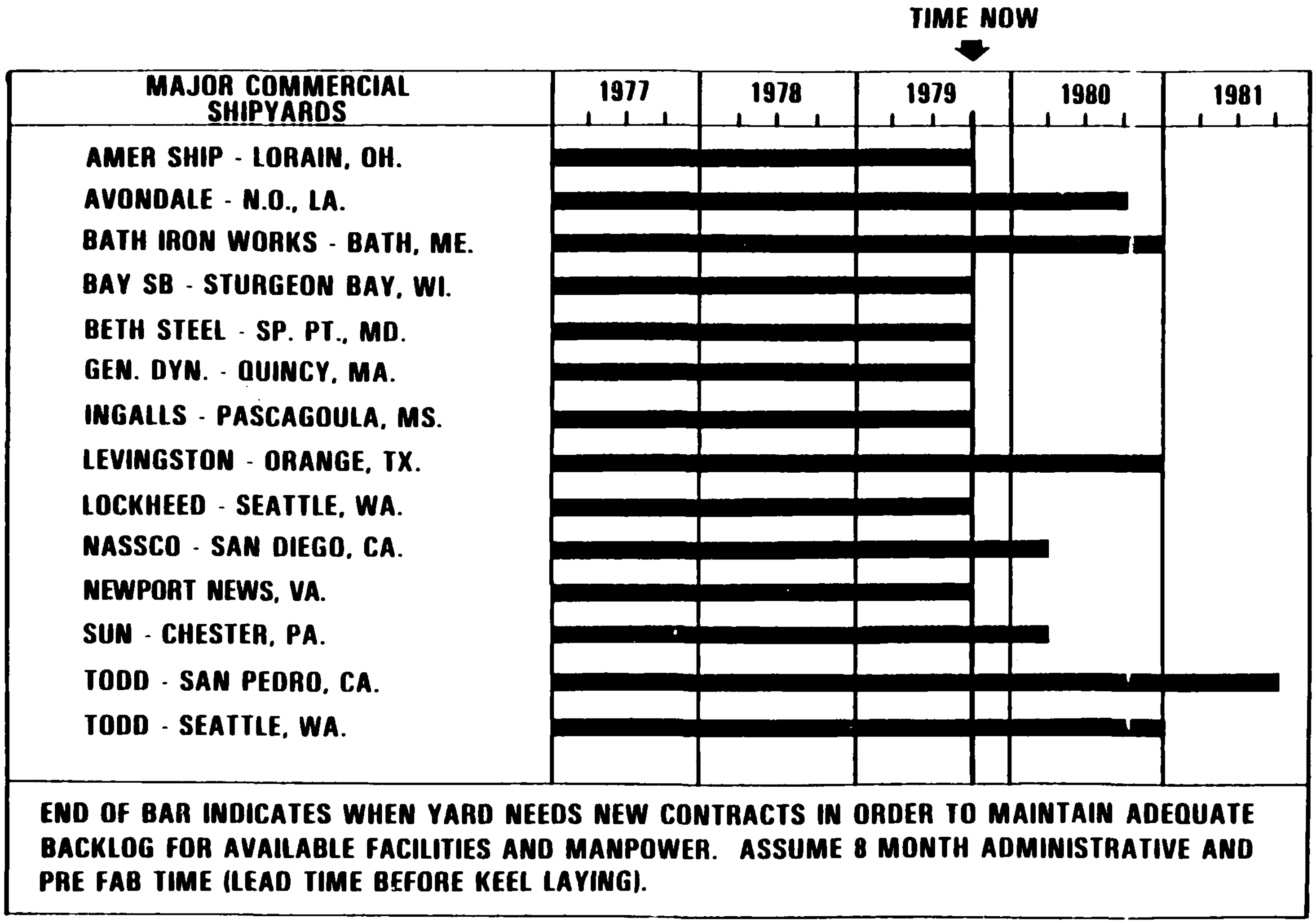

Figure 2-3. SHIPYARD STATUS: NEED FOR NEW BUSINESS (U.S. DEPARTMENT OF COMMERCE, MARITIME ADMINISTRATION)

is underway. Moreover, the trends in labor force usage analyzed in Section B.3.c reinforce this hope of a movement toward a larger capital/labor ratio.

The influx of the conglomerates into the industry in the 1960's was inspired in a measure by capital needs beyond the resources of the industry. During that period ships increased dramatically in length, width, and depth, demanding larger building ways, berthing space, and dry docks. The period also experienced great leaps forward in ship complexity--naval and commercial--and saw the size of tankers grow by quantum leaps. New technology offered the venturesome management the possibility of pioneering LNG and LPG tankers. And the series production techniques of the automotive and aerospace industries, coupled with the stress on economies by DoD, tempted conglomerates to invest in facilities for series production in shipbuilding.

Today, the heady dreams of extensive application of series production and unlimited tanker demand are over, but the potential for and need of extensive investment to enhance productivity and profitability remain. Specialized production facilities; the use of computer-assisted management and design methods; numerical control in lofting and fabrication processes; automatic and semiautomatic welding equipment; and larger lifting equipment to accommodate the increased use of modular construction--all have provided technological impetus to increasing investment. Increasingly in the near future laser welding and alignment, plasma cutting, air-lift and water bearing materials handling, and, perhaps to some degree, robotization will offer a large investment incentive to the relevant yards.

However, the industry has been and is likely to remain a laggard in capital intensity for several important reasons. First, as shall be argued in Section C.4, the industry's profitability is low, and therefore generates neither the cash flow

nor the rate of return available to profit-wise management in other endeavors. Indeed, on solid economic grounds of efficient resource usage, the industry should not be a prime recipient of scarce investment resources under current and prospective conditions. Second, the nature of the demand factors which were examined in Section B.2 gives management only the riskiest bases for estimating the profitability of capital projects. It may be the best response to such uncertainty to retain less efficient but more flexible factor mixes with a larger labor component capable of layoff than would be appropriate if workloads were stabilized over the years. Lastly, even if profitability and stability were instituted in the industry, the overhang of excess capacity both nationally and internationally militates against the need for horizontal capital extension. The products of the industry are not expected to enjoy a long-term demand growth that would press for expansion of existing or building of green-field facilities.

It is concluded, therefore, that investment opportunities in the industry during the coming decade will spring almost wholly from the need to prepare to specialize in production or introduce cost-saving technical processes. Cash flow inadequacies, unstable demand, and the tempered need to innovate that is inevitably felt by a subsidized, protected industry whose procurement methods deemphasize price and spread work, should act to discourage the rapid adoption of improved technology.

3. Productivity

No economic concept is more difficult to measure than that of "productivity." Ideally, it should be indexed by a measure of physical output (properly adjusted for quality changes in the product) per unit of total resources cooperating in production. However, each term in the definition offers insoluble

problems. Physical outputs are heterogenous, so that a ton of nuclear aircraft carrier is quite different from a ton of bulk carrier. The increasing complexity of ships guarantees that one ton of destroyer in 1980 will be quite different in resource content and use capability than that ton of destroyer in 1970. Hence, intertemporal comparisons of productivity measures are difficult, even in the production of the "same" good. Also, there is no manner to add units of labor, capital, and materials to arrive at a measure of total resources employed.

Perhaps the most accurate overall index of productivity in an industry would be profitability in an economic sense of net revenue divided by total capital invested. However, to be useful profits would have to be earned in a competitive environment in which neither buyers nor sellers possessed power over price and in which both were fully subject to economic incentives. These characteristics do not presently exist in shipbuilding. Further, it is difficult to disentangle economic profit from accounting/financial profit.

The difficulties of measurement lead to two complementary but hardly satisfying indications. The first is value added per worker or per production worker. It should vary with the quantity and quality of capital employed as well as the skill and dedication of the labor force. It is, of course, an imperfect index of total resource productivity, not labor efficiency alone, despite its method of construction. The second route is to seek the opinions of management concerning trends in productivity, discounting somewhat an inclination to view labor's performance through an adversary's lens.

It was demonstrated in Table 2-17 that in 1977, on a cross-sectional basis, value added per worker in shipbuilding was the lowest of the sample of comparison industries, as was value added per production worker hour. Certainly this is not surprising in view of the analysis of labor usage and turnover and lagging

capital formation that still characterize the industry. Table 2-34 presents estimates by the Department of Commerce of the real value of shipments per employee for a sample of durable goods-producing industries. They are deficient from several additional points of view for the aims of this study. Value added would have been a better measure since it abstracts from the high and rising absorption of increasingly complex and expensive off-site materials and components, especially in shipbuilding. Second, in shipbuilding the long production periods permit value of work *performed* in a year to differ materially from value of work *delivered* as shipments in that year, especially in periods of inflation. A lagged measure would have been preferable. Third, value of shipments per employee will vary with fluctuations in the employment level from year to year. Lastly, the differences among industries in total employment/production employment ratios would have made shipments per production worker more indicative. Our belief is that the first and third of these considerations bias the measures in shipbuilding's favor. The second criticism has an uncertain impact.

The trends over this brief period--which included the most severe postwar recession and the adjustment to OPEC price rises--reveal that shipbuilding's rate of growth in per worker shipments is lower than every included industry except guided missiles. Nonetheless, it is a respectable rate, especially for an industry in which the series production techniques of the others are not available.

More informal evidence presents a less comforting picture. Every shipyard management interviewed answered positively the question of whether productivity of labor had declined in the last ten years. Most blamed the decline upon what they discerned as a less efficient labor force, characterized by high turnover, less experience, and significantly less devotion to the work ethic of former times.

Table 2-34. REAL VALUE OF SHIPMENTS PER EMPLOYEE FOR A SELECTED GROUP OF DURABLE EQUIPMENT INDUSTRIES, 1972-1976 (IN CONSTANT 1976 DOLLARS)

Industry	1972	1973	1974	1975[a]	1976[a]	Annual Growth Rate
Shipbuilding and repair	$17,302	$20,060	$24,886	$33,270	$31,030	15.7
Automobiles	94,529	99,237	98,600	126,001	173,333	16.4
Aircraft	28,872	34,408	40,754	54,681	60,664	20.4
Aircraft engines and parts	26,384	30,609	35,375	44,441	49,869	17.3
Guided missiles	26,963	30,527	36,878	46,566	44,299	13.2

[a] Estimated.

Source: U.S. Department of Commerce, [40].

On these bases, in addition to those analyzed in the treatment of the capital base, it is felt that the shipbuilding industry does lag in the efficiency with which inputs are converted to outputs, both relative to other similarly placed industries and to the state-of-the-art technology available. The nature of the product also does not lend itself to enjoying economies of mass production. However, the *degree* to which the industry lags others and the state-of-the-art is impossible to judge from data and studies in the literature. Most importantly, the methodology for making such quantitative judgments does not exist.

4. Profitability and Financial Health

The profitability of the relevant shipyards must be inferred from inadequate data, order-of-magnitude macro procedures, and impressionistic evidence garnered from a variety of sources. The tableau constructed by this methodology presents a consistent overview of the industry, but attempts to focus on detail fail because the data base is weak.

The ideal measure of industry health from the economist's viewpoint is the concept of "economic profit"--the surplus of total revenues for a period over total costs, where the latter include all factor costs, a charge for depreciation that reflects true capital waste, and a competitive charge for the wages of management. This quantity would measure the margin of maneuverability that industry had above the economic costs of all its resources. Were it zero, the industry would be just self-sustaining as an economic entity; if negative, the industry would not be recovering total costs; and if positive, the industry would be more than ordinarily remunerative, by virtue of extraordinary demand for its products, greater than typical cost efficiency, and/or monopoly power to some degree over pricing.

Of course, accurate measurement of this concept of profitability is beyond our powers. Corporate data on financial profits are not readily available, since, as has been seen, most major yards are owned by multi-profit center corporations who do not break them down by centers. Valuation of capital and the costing of its economic waste and usage are thorny problems, as is the estimation of necessary management return.

Nonetheless it is believed that, for the overall relevant industry, this economic profit is currently negative: the industry is not returning its full costs over the long term and hence the underlying economic attraction to new entrants or new investment does not approach that of other industries.

In the *Profits '76* study of profits in a set of defense industries it was estimated on the basis of sample studies that shipbuilding firms averaged between four and six percent return on all assets *before taxes* in the period 1970-1974, compared with 11 to 18 percent for all firms in the study. The

average return for shipbuilding firms over the five-year period was only 4.2 percent--by far the lowest of the defense industries rated. It should be noted that the study deducted the generous progress payments made by the Navy to the industry.[1]

An Institute for Defense Analyses study in May, 1978, using a different methodology that estimated the rate of return for the industry from profit margins on sales and sales to asset ratios, was in close agreement with this finding. It found that in the period 1967-1975, before tax profit rates on total assets for the larger yards was between 5.2 to 6.3 percent.[2] Considering the difference in time periods, sample firms and methodologies, this correspondence with the *Profits '76* rates is quite close. *Comparatively,* then, with respect to other industries in general and defense industries in particular, shipbuilding registers as a poor relation.

These estimates, of course, are not economic profit rates, but rather "refined" financial rates. However, they are strongly indicative that in the first five or six years of the decade just ended, economic profit was negative.

Unrefined financial data for the industry in this period tend to confirm this impression. The IDA study quoted above also studied two samples of firms, using data from an association of bank credit and loan officers and from Standard and Poors. The data are not restricted to shipyards and for the latter do not include only the relevant yards. Hence, the conclusions of the study--for the period 1966-1975--are only indicative, not definitive.

Sample 1 industries included approximately 50 firms in SIC 3731, ship and boat building and repairing. In Sample 2, only five large publicly-held shipbuilding firms whose marine

[1]U.S. Department of Defense, [41].

[2]John D. Morgan, *et al.*, [21].

construction exceeded 30 percent of 1975 sales are included. These data reflect, of course, profits from and assets devoted to other production than shipbuilding. In both samples, firms from other industries are included for comparative purposes. The findings are summarized in Table 2-35.

For the larger shipyards of Sample 2, the nine-year average return on total assets before taxes was below that of all groups except aerospace, and corresponds rather well with the estimates made by *Profits '76* and the "refined" financial analysis of the IDA study (which was done independently). Profits before taxes as a return on net worth reveal the same pattern, and certainly after taxes would imply a less than satisfactory performance, considering that the *after-tax* return on net worth was 12.5 percent over the period for the Standard and Poors 400 Industrial Companies.

For the broader sample of about 50 shipyards in Sample 1, the profits picture is somewhat brighter in a comparative sense. Profit margins were twice as high as those of the smaller sample, possibly reflecting the larger ship repairing component in the sample. Profit before taxes on net worth was among the highest of the group included at about 20 percent, whereas on total assets it was somewhat worse. It should be noted that in order to get a more accurate picture of total returns to capital, all of these calculations involving total assets should include interest payments as well as profits. Since debt equity ratios in both samples for shipbuilding are higher than most other groups, this adjustment would have favored the shipbuilding industry's performance. Moreover, progress payments should be deducted from the capital base, and because these were peculiarly generous to shipbuilding this procedure also would have favored the industry's rate of return. Even with these adjustments, however, it seems likely that the average rate of

Table 2-35. INDUSTRY FINANCIAL HEALTH STATISTICS

	PBT/NW	PBT/Total Assets	PBT/Sales	Sales/Working Capital	Current Liabilities/NW	Total Debt/Equity	Long Term Debt/Equity	Assets/Sales
A. Sample 1 Industries - Ten Year Averages - 1966-1975								
11 Defense Contractors[a]	19.4	7.3	4.8	6.6	1.10	1.40	0.44	0.62
Fabricated Structural Steel	16.1	7.4	5.4	6.5	0.67	1.10	0.27	0.52
General Industrial Machines	19.1	9.7	7.3	4.9	0.53	0.90	0.23	0.6[illegible]
Equipment-Public Utilities	19.9	9.8	7.0	4.5	0.49	0.90	0.29	0.60
Drugs and Medicines	21.0	10.2	9.6	4.7	0.50	0.90	0.30	0.60
Motor Vehicle Mfg.	16.8	7.5	5.8[b]	5.8	0.63	1.00	0.29	0.52
A/C Parts except Electric	20.0	10.0	5.7	5.6	0.70	1.10	0.40	0.62
Ship and Boat	20.2	8.2	5.7	7.0	0.78	1.30	0.28	0.52
B. Sample 2 Industries - Nine Year Averages - 1967-1975								
5 Shipbuilders Weighted Average	13.3	5.2	2.9	9.4	1.10	1.50	0.39	0.56
5 Shipbuilders Simple Average	14.7	6.4	4.1	6.8[d]	0.82	1.30	0.50	0.65[d]
65 Aerospace	10.8[c]	3.7[c]	3.8[d]	5.5[e]	1.40[d]	1.95[c]	0.59[c]	0.82[e]
13 Conglomerates	15.1	7.0	6.3	6.6	0.53	1.11	0.59	0.91
11 Defense Contractors	19.3	7.7	4.8	6.9	1.00	1.47	0.44	0.64
S&P 400 Industrials (After-Tax)	12.5							

[a]Nine years of data.
[b]Eight years of data.
[c]Six years of data.
[d]Eight years of data.
[e]Seven years of data.

Note: Abbreviations are: PBT - Profit Before Taxes; NW - Tangible Net Worth.

Sources: Sample 1 data - Robert Morris Associates, *Annual Statement Studies*, 1966-1975. Sample 2 data - Standard and Poors, 1967-1975.

return in shipbuilding for both samples would have remained below the average for all industries.

Other indices of industry health in Table 2-35 confirm the impression of a none-too-vigorous industry. Liquidity measures--sales to working capital and current liabilities to net worth--reflect adversely on the industry relative to the comparison groups. Current ratios for both samples (not shown in Table 2-34) also are slightly lower than those of other groups, but not dramatically. In interpreting these data it is necessary to take into account the reduced need for liquidity that generous progress payments during the period provided, so that the industry's position may not be as disadvantageous as revealed on the surface.

Solvency measures reveal that total debt (i.e., current and long-term) to equity ratios are among the highest for shipbuilding in both samples, reflecting in part the unavailability of the equity market to the industry in this period. The ratio of long-term debt to equity reveals a different picture. On this count shipbuilding in both samples is lower than most of the industries compared. This may reflect the riskier nature of a highly unstable industry, and, together with the evidence of the total debt to equity ratio, reveal the necessity to borrow much of its needed capital at short term rather than at long term.

The IDA analysis concludes in the face of the nonspecificity of the data and the imprecision of interpretation:

> "Recognizing the limitations of the data, it nevertheless appears that in terms of earnings and balance sheet ratios, the shipbuilding industry in general has demonstrated substandard performance compared to other U.S. industries on whom data were collected. Thus, the analysis in this appendix...tends to support the conclusions in Chapter II which were based on more macro-oriented data from federal government sources."[1]

[1] *Ibid.*, page B-1.

A more recent study of profits in the industry, characterized by the same unavailability of specific shipbuilding profits data for the conglomerates, but with privileged access to some proprietary data for the period 1967-1976, broadly supports the conclusions cautiously drawn herein, but with some differences.[1] It has the advantage of dealing with only 13 of the largest companies, and hence is more germane to the relevant yards of this study.

For 11 firms--Avondale, Bath, Newport News, Todd, Electric Boat, Litton, NASSCO, Lockheed, Sun, American, and Alabama--the study estimates the after-tax profit margin over the period at .2. The profitable firms in this sample (i.e., excluding Todd, Litton, Lockheed, and General Dynamics) enjoyed after-tax profit-to-sales ratios of 2.5; the unprofitable, losses of 2.2. The estimate of after-tax profits to net fixed assets for the profitable firms was 9.2 percent. More detailed data for the 13 companies, with 9 of their identities masked by letter designations, are given in Table 2-36.

These data yield a somewhat more favorable picture than the *Profits '76* and IDA studies. If we use the ratio of long-term debt to equity for the 5 large shipyards of the IDA study's Sample 2 (which is .5), and it is assumed that after-tax profits are about 60 percent of before-tax profits, then before-tax profits on net worth plus long term debt--a crude measure of assets--become quite large. Indeed, the positive values of the second column of Table 2-36 are increased by about 11 percent, yielding values of 4.8, 7.8, 15.4, 9.9, 18.3, and 15.7. These estimates are, for the most part, so far outside the estimates of the previous studies that inconsistencies among the studies may be suspected of causing the discrepancies. The hypothesis of the Kaitz study--that, although the relevant industry is overall not a profitable one, there is a group of consistently

[1] Edward M. Kaitz and Associates, Incorporated, [12].

Table 2-36. ESTIMATED PROFIT PERFORMANCE MEASURES, 13 LARGE SHIPYARD COMPANIES, 1967-1976

Company	After Tax Profits/Sales	After Tax Profit/Net Worth
1. Bath	1.8%	4.3%
2. Newport News	2.3	7.0
3. Electric Boat	-1.8	b
4. Lockheed	-5.8	b
5. Firm A	1.9	13.9
6. Firm B	-1.3	-5.1
7. Firm C	-2.3	-95.0
8. Firm D	3.2	8.9
9. Firm E	3.0	16.5
10. Firm F	a	a
11. Firm G	a	a
12. Firm H	4.7	12.4
13. Firm I	3.8	14.1

[a] No longer identifiable as a firm.

[b] Unknown.

Source: Edward M. Kaitz & Associates, Inc., [12], p.13.

profitable firms within it which tends to contain the old-line, smaller firms--is an interesting one. Overall, however, for the macro view taken in this chapter, there is support for the assertion that the industry is less-than-average in its profitability.

The informal and indirect evidence supports this admittedly imprecise conclusion. Most of the analysis of the structure, performance, and conduct of the industry as presented in this chapter leads to this expectation. The consistent burden of management in congressional hearings in the mid-1970s was that of insufficient profits, especially on Navy contracts. And, in interviews, as noted, a widespread belief exists that

the next decade will see a substantial shakeout of the industry because of overcapacity and unprofitable firms within the relevant group.

D. SUMMARY AND CONCLUSIONS

That segment of the United States shipbuilding industry which produces ocean going vessels is an uneconomic sector which, for the most part, would disappear were it not for the substantial protection and subsidies it enjoys from national maritime policy. In this respect it does not differ from its counterparts in other mature industrial nations.

The product it produces is one of the most durable made outside of the construction industry. As a capital good in the commercial sector, merchant ships provide services that are highly vulnerable to world economic conditions, and by well known economic mechanisms the demand for new merchant ships has this cyclical and noncyclical instability transmitted to it in a magnified form.

In both commercial and military sectors, the product cannot be mass-produced: the number produced in any series is in the vast majority of the cases too small for series production, and design changes within the series are too many. Each ship is, in a sense, a tailored product, produced by extremely expensive skilled labor without access to specialized, automated equipment. The great--and increasing--complexity of the product, compounded by the extremely long production periods necessary for its production, inflict high risks of cost, time, and technical miscalculation upon management, given the extremely intricate long-term time-phasing of labor and materials that efficient operation requires. Progress curves are shallow and their economies easily swamped by uncompensated inflationary price movements and the costs of coping with the unforeseen.

The uncertain year-to-year workload has led firms to adopt labor-intensive methods rather than to sink funds into expensive capital equipment, for the ability to expand and contract labor force gives a much-prized, if expensive, flexibility to a yard's operations. It is a major factor in the high turnover rates that characterize the shipbuilding labor force, although the inability of the industry to pay wages as high as those offered by competing industries and the less attractive working conditions contribute to that costly attribute. The uncertain and unstable workload also has prevented firms from specializing in given types of ships, with consequent loss (to the desire for flexibility) of economies that investment in specialized equipment and facilities would allow.

Productivity and profitability are lower than in similar industries, therefore, and new entrants into the industry rare. Only one truly new shipyard has been built in the United States in the postwar period. For levels of demand that have ruled in that period for ocean-going vessels, a good deal of excess capacity exists in the industry.

Export demand, except for a few specialized product types, is unlikely to be a factor in the American industry's future. For purely economic reasons, then, and from the viewpoint of prospective nonsurge domestic demand in the next decade, the industry should not be considered a candidate for reindustrialization.

Thus, the shipbuilding industry is beset by a number of debilitating characteristics. The extreme variability of demand for its product has contributed to low capital intensity and high labor turnover, with consequent low productivity. Poor profitability is imposed by international competition and naval contracting policy, and worsened by dependence on suppliers over whom little influence exists. Without increases in demand for its product, that demand being directly or

indirectly determined largely by government policy, substantial shrinkage of the industry seems likely over the medium term.

The national policy toward shipbuilding will have to be shaped by largely noneconomic factors. What degree of subsidization--both direct and indirect--is it worthwhile to engage in for national security purposes? How much excess capacity should be supported as an insurance against surge demands for mobilization or war?

These questions require that a national policy determine the maximum production effort in shipbuilding that policy-makers are willing to provide the base for by one form of subsidy or another. Using CMP methods[1] the shipbuilding program representing that maximum production effort can be analyzed to determine the yards necessary for its production, and cost analysis can be employed to estimate the cheapest manner of allocating normal demands among the maximal set of yards so that their preservation is assured.

Before this determination of a necessary preservation base can be made rationally, however, a thorough assessment of the true economic costs to the nation of maintaining a larger number rather than a smaller number of yards in the procurement base should be undertaken.

[1]Chapter I and Chapter IV.

Chapter III

SOME FACTORS AFFECTING CAPACITY AND EXPANSION POTENTIAL OF THE U.S. SHIPBUILDING INDUSTRY

A. INTRODUCTION

1. The Context of Shipbuilding Capacity Measures

Chapter IV will analyze the varying effects which alternative programs of naval and merchant ship construction might have upon the shipbuilding industry. In two of the cases considered there, the level of building activity is considerably higher than at present. Therefore, it is important to know if the industry has sufficient capacity to expand at the projected rates. In addition, alternative distributions of the ship construction program over the existing shipbuilding concerns will also be of interest. This chapter will discuss those factors affecting the rate of expansion on which there exists enough evidence to generate hypotheses for the analysis that will follow. Construction of new yards, or the costs of expanding the use of existing yards for new naval ship construction were not examined.

Generally speaking, the building of a ship requires the following physical elements:

(1) A *place* to build and launch a ship.

(2) The requisite tools and machines to form and assemble the parts.

(3) An organization to assemble the men and materials and direct the work.

(4) A force of labor possessed of the necessary skills.

(5) A group of specialized producers of parts and devices not produced (or not producible) at the work site.

The other elements of any industrial activity such as transportation and other services, we can assume to be present.

The present situation of the industry will be considered with regard to these five factors and how they might affect and be affected by differing shipbuilding programs: first, the firms now in the industry (summarizing from Chapter II); then, the number of building positions available and their current utilization (along with synopsizing the yard equipment capability); then, the supporting industries; and, finally, the overall labor situation. However, it is useful to review the nature of shipbuilding to establish clearly the context of the discussion.

2. The Shipbuilding Process[1]

The nature of the typical production process for ocean-going merchant ships and major naval combatants and auxiliaries is implicit in the name of the industry, i.e., "shipbuilding." The process involves construction in place of the hull, the installation of the major interior machinery and equipment and the other interior and exterior outfitting. This differs from the construction of a building in that the final construction in place is preceded by building and outfitting parts of the ship in assemblies (or modules, or blocks) which are, then, transported to and put together on the shipway or in the dock. At various stages after the hull has reached such a degree of completion as to ensure watertight integrity, it is floated (by launching or by flooding the dock) and additional construction and installation are carried out at a fitting dock

[1]The authors are indebted to D.M. Mack-Forlist for his assistance in this summary.

or pier. Eventually the ship reaches a stage at which it can be powered, the various systems are tested at the dock or pier and, finally, in trials at sea, and the completed ship is delivered to its owners/operators.

The term keel-laying is still used to denote the beginning of construction in the dock or on the shipway, but the procedure of laying a separate keel, succeeded by erection of framing and plating of shell, bulkheads and decks, etc., and the piecemeal installation of machinery and outfitting components and materials was being superceded before the war by methods which, in greatly expanded and much more sophisticated forms, are the shipbuilding methods of today. The greatest single impetus for change was the necessity of vastly accelerated construction during the war; the most important technological advance which made this possible was welding.

Great advances have been made since the war. Some examples are special "hot" welding electrodes, plasma cutting and welding, optical lay-out and tape-controlled lofting and cutting, mechanized assembly (panelshops), mechanized semi-automatic frame and pipe bending and semi-automatic assembly of some piping sections and structural members, photogrammetry, computer applications in design and in production control, etc. Many of these innovations were made in the 1950's and 1960's and the process is continuing today with the greatest present emphasis on labor saving and software.

Today the ships are built in a series of assemblies, some of which may be segments of the hull from bottom to the top deck. These are pre-outfitted to varying degrees, sometimes to the point of plumbing, electrical light fixtures and deck-covering. While this mode of construction--pre-assembly and pre-outfitting--is universal, the degree depends on the facilities of the shipyard and the type and design of the ship.

These methods offer major economies because of the easy access to the work, easier material handling, better access to utilities, elimination of much of the staging and shoring (because the work can be positioned, particularly for downhand welding and because it permits shorter occupancy, i.e., greater output for the shipyards' most expensive and controlling facility--the building position). The full additional advantage of extensive use of jigs, fixtures and special tools can only be obtained with the construction of series' of similar ships.

The process of building the ship and outfitting it involves complex scheduling and combining labor of various skills with flows of raw, semifinished and finished materials, devices and fittings, forgings and castings, parts and systems. These must be put into the ship in a limited number of orderings in time--thus the delay of one item can theoretically delay the whole process, although there are often alternatives. The installation of the propeller ought to take place before the ship is launched; however, it is possible to do it after launch in drydock. As this example illustrates, such rescheduling is very often at the expense of additional cost and use of additional facilities.

The process is complex because the ships are put together out of hundreds of thousands of pieces and components, each piece and component going through a number of steps at a number of locations, each step involving a number of people and different tools and processes. There are many millions, in the bigger and more complex ships tens of millions, of actions and events, each interrelated with and interacting with several others. It is this that makes ships complex products and shipbuilding a complex operation.

B. SHIPBUILDING ORGANIZATIONS

The general structure and characteristics of the shipbuilding industry have been reviewed in Chapter II. Table 3-1 below recalls the U.S. firms which own the major shipbuilding facilities.

Table 3-1. OWNERSHIP PATTERNS OF SHIPYARDS

	Category I & II Yards [a]
1. Private Organizations Controlling Subsidiary or Facility	
Bethlehem Steel Corporation	Sparrows Point Shipyard
Congoleum Corporation	Bath Iron Works
General Dynamics	Electric Boat Division Quincy Shipbuilding Division
Morrison Knudsen, Inc.	National Steel and Shipbuilding Company (NAASCO)
Litton Industries	Ingalls Shipyard
Lockheed Aircraft	Lockheed Shipbuilding and Construction
Ogden Corporation	Avondale Shipyards
Sun Oil Company	Sun Shipbuilding
Tenneco, Inc.	Newport News Shipbuilding and Drydock
Todd Shipyards, Inc.	Todd San Pedro Shipyard Todd Seattle Shipyard
2. Publicly Owned U.S. Navy	Charleston, SC, Naval Shipyard Long Beach, CA, Naval Shipyard Mare Island, CA, Naval Shipyard Norfolk, VA, Naval Shipyard Pearl Harbor, HI, Naval Shipyard Philadelphia, PA, Naval Shipyard Portsmouth, NH, Naval Shipyard Puget Sound, WA, Naval Shipyard

[a]Less Marinette Marine.

Source: Richard E. Ames, *et. al.*, [1].

The eight public shipyards of the U.S. Navy have been confined to overhaul and repair since 1972. Four of the yards have maintained a construction capability in being--specifically, Portsmouth, Philadelphia, Mare Island and Puget Sound.

One can argue, on the other hand, that each shipyard is the appropriate organizational entity and that the decentralized management of corporate conglomerates permits a high degree of managerial and financial independence of action by a well-managed subsidiary. Some complexities of the situation have been indicated in the discussion in Chapter II. Thus, focusing upon the shipyards may be more useful in assessing shipbuilding capacity.

C. SHIPYARDS

1. Building Positions as Elements of Capacity

The simplest measure of capacity is the number of places to build a ship. This is to say, the number of ships under construction at any one time cannot exceed the number of places where a ship can be constructed. A "place" to build a ship or "building position" requires: a dry area to erect the framework of the hull, hoisting machinery to move heavy pieces of the ship into place, and a means of placing the completed hull in the water. Figure 3-1[1] below is a plot plan of the San Diego facility of National Steel and Shipbuilding Company showing (1) a graving dock, which is a basin below water level that may be flooded when the ship being constructed is ready to be floated, (2) three slip ways, that is, inclined hard surfaces with a keel blocks along which the completed hull slides on cradles into the water and (3) a floating drydock, where a ship can be constructed or repaired and then floated out via flooding the drydock. The other facilities for handling plate steel, fabricating sections by welding and bending, cutting

[1]MARAD [38], p. 70.

EXHIBIT 23

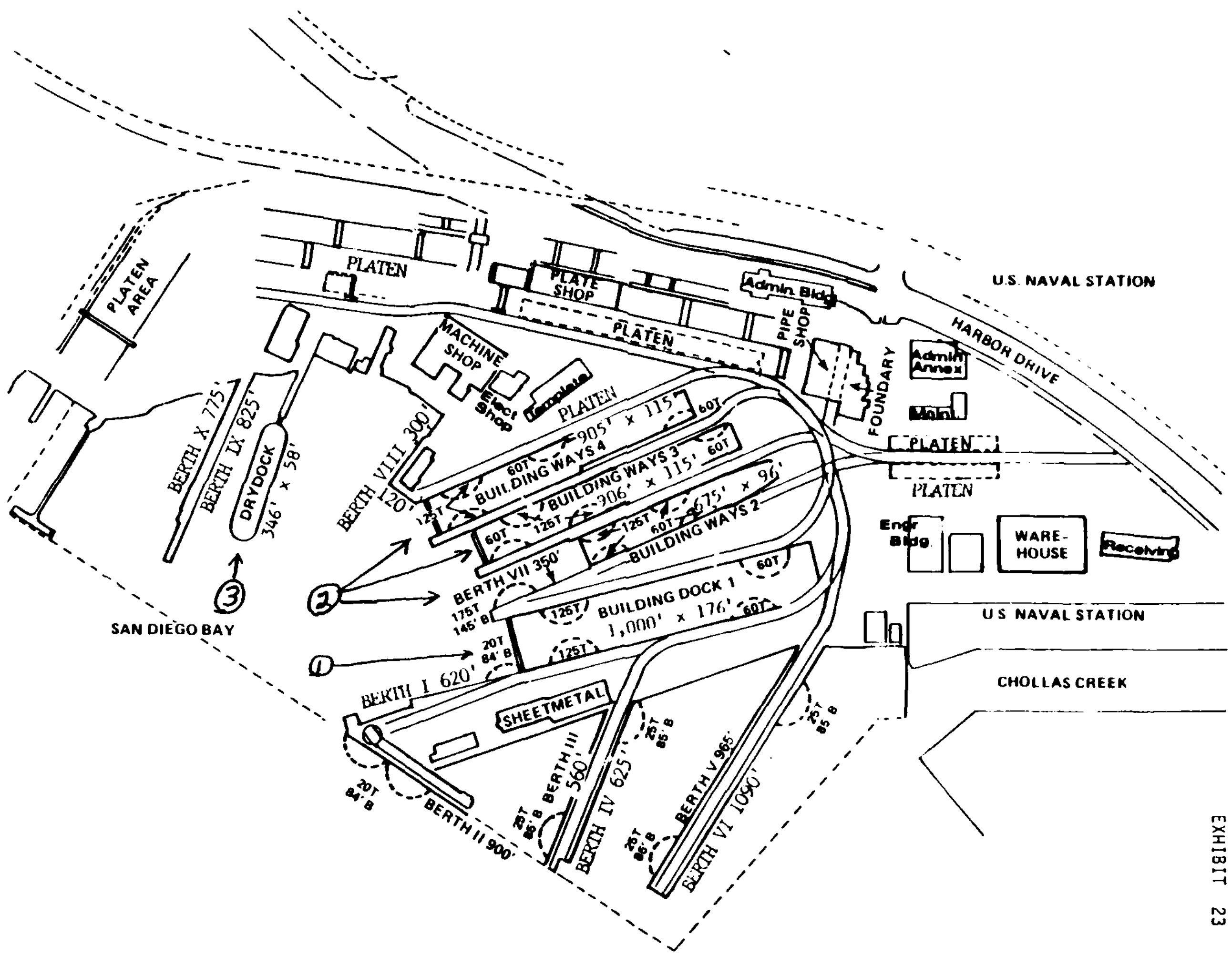

Figure 3-1. NATIONAL STEEL AND SHIPBUILDING CO.

pipe, making castings and forgings, etc., are shown on the plan. This is a more or less traditional yard.

The plot plan of a more recently built yard is shown in Figure 3-2.[1] This is the West Bank facility of Ingalls Shipbuilding at Pascagoula, Mississippi. Here the separate sections (modules) that make up a ship are assembled in the five bays, which can make sections as long as 225 feet and weighing up to 6,000 tons. Completed modules are shifted to the integration area to be welded into a hull, which is then moved onto the pontoon. The pontoon and hull are towed to deep water where the hull is launched by sinking the pontoon. This arrangement is said to be the equivalent of six slipways or drydocks.[2]

D. BUILDING POSITION CAPACITY OF US SHIPBUILDING

1. The Set of Shipyards

Before listing the number and size class of building positions potentially available to the U.S., it is important to explain the various classifications. In its FY 1981 appropriations testimony,[3] the U.S. Navy distinguished 12 "Major Private Shipyards" that are building or have built "major" ships for the Navy.[4] The implication is that these yards are the only ones likely to build or be interested in building the Navy's combat and auxiliary ships in the future.

This is only a gross measure of capacity for descriptive purposes--the business of allocation of ships (both naval and commercial) to facilities is covered in Chapter IV.

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[1] *Ibid.*, pp. 61.

[2] *Ibid.*, pp. 22, 23.

[3] U.S. Congress [35], pp. 61, 63.

[4] These are the same as Category I and II, less Marinette Marine.

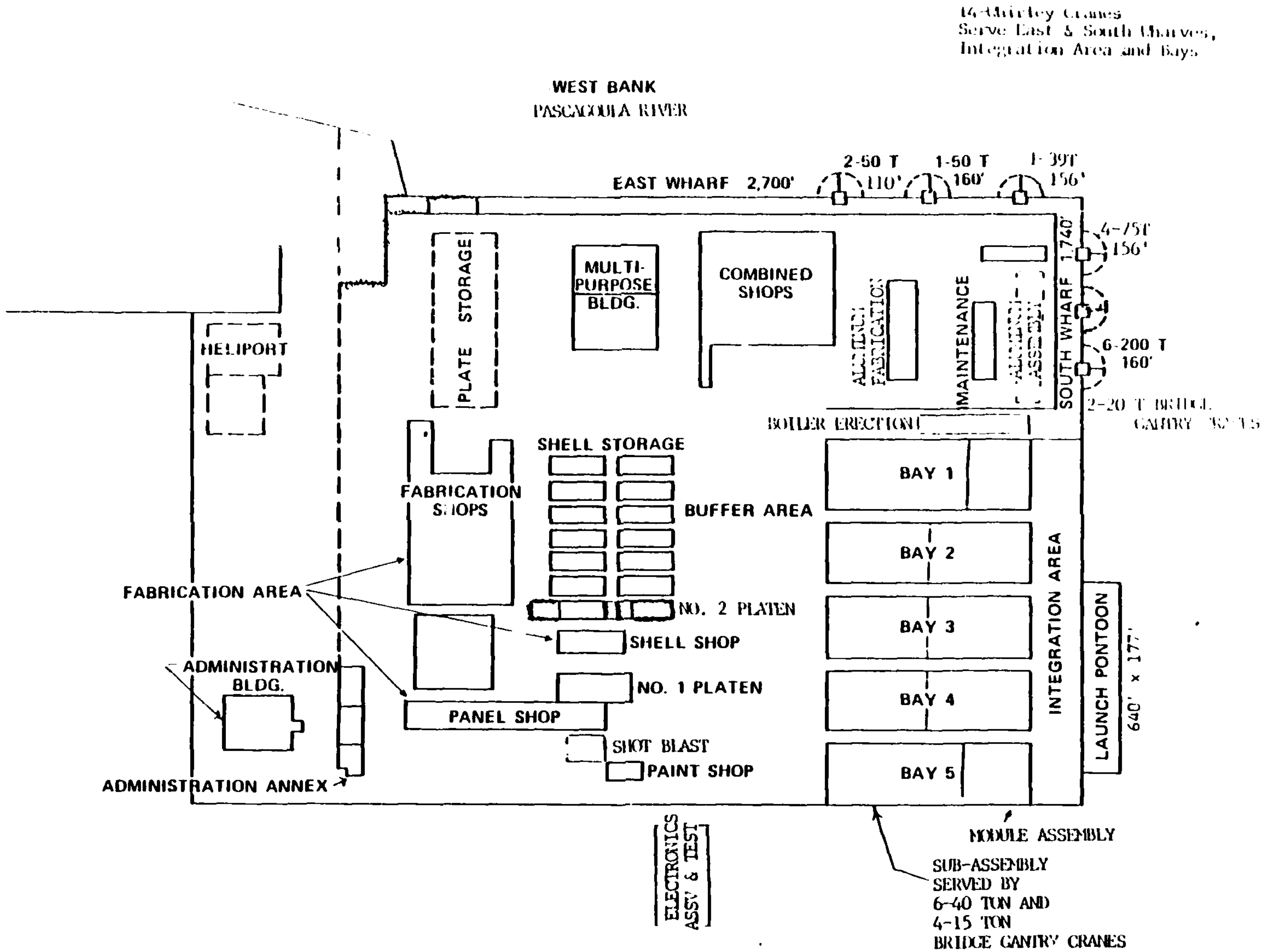

Figure 3-2. INGALLS SHIPBUILDING (DIVISION OF LITTON SYSTEMS, INC.)

In addition to these 12, there are 15 other yards classified as "Major Private Shipyards" in G.M. Cole, [3].[1] These are yards with interest in new construction (either Navy or commercial) and the capability to build large ships (building positions at least 475 feet or longer capacity). Looking at nothing except a *place* to construct a hull (other facilities are, of course, needed) the number of building positions in these yards could be considered to dimension building capacity.

2. The Number and Size of Building Positions

Finally, there are additional yards with floating drydocks, graving docks or marine railways that could be used for building, though the yards currently are engaged primarily in ship repair. Again, if the 475 foot length is specified, this gives another 20 facilities. Table 3-2 summarizes the data.

In addition to the commercial building positions, there are graving and drydocks at naval shipyards that were used for construction until 1972 and are currently being used for repair. Table 3-3 shows the distribution among the four most recent building yards and the repair-only yards.

These yards are currently engaged only in repair and overhaul of U.S. Navy ships. They have not been included in the capacity estimates of this chapter. Should the four lead yards be returned to building, it would add potential of about 20 percent to that of the 12 major shipyards.

3. The Sizes of Ships

The commercial yard building positions, with due allowance for the capacity of such facilities as Ingalls West Bank, set

[1]These include 5 Category II plus 10 other yards.

[2]The allocations by NAVSEA and IDA reported in Chapter IV below utilized 32 private yards of the 47 possible candidates whose facilities are listed in this table.

Table 3-2. SHIPYARD BUILDING POSITIONS (LENGTHS BY SIZE CLASS AS GREAT OR GREATER IN FEET)

Group	Area	Shipyard	475	550	600	650	700	750	800	850	900	950	1000	1050
12 Major	Atlantic	Bath Iron Works	3	3	3	3	2							
		General Dynamics Quincy	5	5	5	5	5	5	5	5	1			
		Elec. Boat	9	9	9									
		Sun Shipbuilding	4	4	4	4	4	1	1	1	1	1	1	1
		Bethlehem Steel Sparrows Point	3	3	3	3	3	3	3	3	3	1	1	1
		Newport News	6	6	6	6	6	5	5	5	5	3	2	2
	Gulf	Litton-Ingalls	12	12	11	11	6	6	6					
		Avondale	12	9	9	8	8	5	8	8	8	8	8	8
	West Coast	Nat'l Steel	4	4	4	4	3	3	3	3	3	1		
		Todd San Pedro	2	2	2	2	2	2	2					
		Lockheed-Seattle	3	3	3	3	1							
		Todd Seattle	1	1										
	Subtotal		64	61	59	49	40	33	33	25	21	14	12	12
15 Ship-builders (new construction)	Atlantic	Maryland SB&DD	1	1	1	1	1	1	1	1				
		Norfolk SB&DD	1											
	Gulf	Alabama DD&SB	5	1	1									
		Bethlehem-Beamont	1	1	1	1	1	1	1					
		Galveston SB	1	1	1	1	1							
		Livingston SB	2	2	1	1	1							
		Marathon LeToureau	1	1	1	1	1	1	1	1	1	1	1	1
		Tampa Ship Depart.	1											
	West Coast	Bethlehem San Francisco	1	1										
		FMC Corp.	1	1	1	1	1							
		Triple "A"	3	3	3	3	3	2	2	2	2	2	1	1
	Great Lakes	American SB Lorraine	2	2	2	2	2	1	1	1	1	1	1	
		Toledo	2	1	1	1								
		Bay SB	2	2	2	2	2	2	1	1	1	1	1	1
		Fraser SY	2	2	2	1	1	1	1					
	Subtotal		26	20	17	15	14	9	8	6	5	5	4	3
27 Shipbuilder - Subtotal			90	81	76	64	54	42	41	31	26	19	16	15
20 Repair Yards	All Areas		37	31	28	21	13	9	7	5	5	3	3	3
Grand Total			127	112	104	85	67	51	48	36	31	22	19	18
Less (Submarine Only)			118	103	95	85	67	51	48	36	31	22	19	18
Less (St. Lawrence Limits)			118	103	95	85	67	42	40	10	26	17	15	15

Source: MARAD, [38].

Table 3-3. POTENTIAL BUILDING POSITIONS AT US NAVAL SHIPYARDS, LENGTH CLASS, EQUAL TO OR GREATER THAN, IN FEET

	Number of Positions												
	475	500	550	600	650	700	750	800	850	900	950	1000	1050
Naval Shipyard													
Building Yards (1959-1972)													
Portsmouth (NH)[a]	2	2	2	2	2	2							
Philadelphia (PA)	4	4	4	4	4	4	3	3	3	3	3	3	2
Mare Island (CA)[a]	3	3	2	2	2	1							
Puget Sound (WA)	6	6	6	6	4	4	4	4	4	4	3	3	1
Subtotal	13	13	12	12	12	11	7	7	7	7	6	6	3
Repair Yards													
Norfolk (VA)	4	3	3	3	3	3	2	2	2	2	2	2	1
Charleston (SC)	3	3	3	2	1	1	1						
Long Beach (CA)	3	3	3	3	1	1	1	1	1	1	1	1	1
Pearl Harbor (HI)	4	3	3	3	3	3	3	3	3	3	3	3	1
Subtotal	14	12	12	11	8	8	7	6	6	6	6	6	2
Total	27	25	24	23	20	19	14	13	13	12	12	12	5

Source: MARAD, [38].

[a]Totals do not include sliding ways at Mare Island (4) and Portsmouth (3).

a limit to the number of ships that can be under construction simultaneously. However, that limit depends on the size distribution of ships. That is to say, each position is limited to some width (beam) and length maximum for a ship or ship section. Reference [38] has the limiting dimensions of all major yards--except for General Dynamics' Electric Boat facility.

As for naval vessels, Table 3-4 presents the principal dimensions of all current building classes and those classes proposed to be begun in the next ten years. Using the two sets of dimensions and data for the average time a hull (of a given class) occupies a building position, a gross measure of building capacity can be provided.

4. A Throughput Estimate

Given the number of building positions by size, one can use the ship dimensions in Table 3-5 to determine (theoretically only) how many of each type could be building simultaneously, given a building position as the only constraint. If it is assumed that only Newport News and General Dynamics' Electric Boat will fill the SSN and SSBN requirements, and CGN and CVN building is limited to the only currently qualified nuclear yard, Newport News, the number of building positions can be reduced. The table shows what ships the 12 major yards (less the CVN, CGN, and SSN/SSBN) could be simultaneously building.

Table 3-6 only lists one group of an almost limitless set of possibilities and is not a realistic building objective. It it interesting only in that it shows some measure of the bounds of the problem of capacity. Since the larger hulls generally occupy the positions for longer times, it is useful to consider what the throughput bounds would be. Data supplied by the U.S. Navy on recent performance in terms of keel-to-launch

Table 3-4. APPROXIMATE HULL DIMENSIONS OF US MAJOR NAVAL COMBATANT AND SUPPORT SHIPS

Class	Length (in Feet) (Waterline)	Beam (in Feet)
CVN-68	1092	134
CVV	910	128
AOE 1	793	107
LHA 1	778	106
AOR 1	659	96
AS 36	646	85
AD 41	643	85
LCC 19	620	82
LPH 2	602	84
AO 177	592	88
CGN 38	585	63
AFS 1	581	79
LKA 113	576	62
LPD 4	570	100
AE 26	564	81
DDG 993	564	55
CGN 42	560	63
SSBN 726	560	42
LSD 41	553	84
LST 1179	523	70
FFG-7	453	45
FF 1052	438	47
SSN 688	360	33

Source: NAVSEA and [11].

Table 3-5. SIMULTANEOUS NUMBER OF KEELS BY SIZE: 12 MAJOR SHIPBUILDERS LESS NUCLEAR PROJECTS

Ship Types by Size	FF,FFG	LST,DD,DDG	LSD,CG,AE, LPD,LKA,AFS, AO,LPH	LCC,AD,AS	AOR	AOE,CVV(CV) LHA	
(Alternatives Maximizing Successively Larger Ship Types)	112	0	0	0	0	0	0
	15	97	0	0	0	0	0
	15	08	89	0	0	0	0
	15	08	10	79	0	0	0
	15	08	10	18	61	0	0
	15	08	10	18	27	34	0
	15	08	10	18	27	21	13

Source: Tables 3-2, 3-3, 3-4

Table 3-6. THROUGHPUT PER BUILDING POSITION BASED ON RECENT[a] AVERAGE KEEL-TO-LAUNCH TIMES

Ship Class	Keel-to-Launch (Months)	Throughput in Hulls/Year Per Position (or Equivalent)
FRG	12	1.00
AE	14	0.86
DD	15	0.80
AOR	18	0.67
LSD	19	0.63
AS	21	0.57
LHA	35	0.34
CV[b]	38	0.32

[a]Averages of actual ships delivered since 1970.

[b]Recent data not available, so NAVSEA estimate used.

Source: NAVSEA.

times for various projects permit us to compute the following approximations for at least one ship in each size class.

Thus, the "position-constrained" annual output rate consonant with the last line of Table 3-5 would be:

Size Type	Hulls per Year
FF, etc.	15
DD, etc.	6.4
AE, LSD, etc.	6.3--8.6
AS, etc.	10.3
AOR	18.1
LHA	7.1
CVN	4.1

It must be realized, however, that lead times of many years would be required before deliveries at the yearly rates shown could be effected; further, other factors besides building position capacity might constrain output to lower rates.

5. Building Positions as a Capacity Constraint and Current Utilization

When one considers the additional capacity shown for the second 15 new construction builders and the potential of repair and overhaul yards, there is clearly no shortage of building positions in the US industry. Most of these, however, are either in old yards and would not be able to match the average keel-to-launch times shown or do not possess the other facilities needed to build complex ships. But if the 12 major yards have position capacity for 65 or more major naval ships per year, it does not seem likely that any Navy program could exceed this. Of course, commercial construction competes for some of this capacity, and the analysis in Chapter IV considers a MARAD projection of commercial demand. Reference [38], as a matter of interest, has the Maritime Administration detailed calculation of the building position capability for each type of current merchant ship for the 27 yards included in the first two categories of Table 3-2.

The NAVSEA and IDA allocations described in Chapter IV take specific account of MARAD-projected merchant marine demand.

Since the longer building positions can accommodate more than one keel and hull of smaller ships, the estimates above of throughput are actually on the low side. Reference [38], for instance, points out that the 1200 foot basin at the Bethlehem Steel Sparrows Point shipyard could be used for one giant tanker or as many as four smaller ships of up to 475 feet in length (an FFG, for example). In the analysis of Chapter IV, this capability to build more than one ship in a position is explicitly considered in estimating surge capacity.

With this in mind, one is in a position to understand the provisional character of the data on current utilization that follows. Based on data supplied in Reference [39], it would appear that in the third quarter of 1980, the following situation existed:

Table 3-7. UTILIZATION OF BUILDING POSITIONS FOR NEW CONSTRUCTION: 1980

Group	Total Positions[a]	In Use	Percent In Use
12 Major Yards	55	39	70.9
15 Shipbuilders	26	8	30.8
Total	81	47	58.0

[a]Electric Boat SSBN and SSN construction and capacity excluded.

Another count of expected utilization for the fourth quarter, 1980 for the 27 (15 + 12) new construction yards, shows the following for building positions of 475 feet or larger:

Table 3-8. NEW SHIPS ON WAYS--FOURTH QUARTER 1980
27 PRIVATE SHIPYARDS
(Building Positions = 90)

Customer	Ship Type	Number
Navy	SSBN	4
	SSN	8
	CG	1
	DD/DDG	2
	FF/FFG	5
	AD	1
	AO	2
Subtotal		23
Private	Tanker	5
	Cargo	5
	Containership	3
	Ferry	1
	Dredge	2
	Barge	5
	Rig	8
Subtotal		29
Total		52 (= 58% of 90)

Source: MARAD [39].

Since this includes both U.S. Navy and commercial ship and barge construction, one could say that the major yards might expand about 39 percent and the others by 60 percent without encountering a building position constraint. However, since many building positions are either graving or floating docks, much of this capacity could be occupied by repair work on existing ships.

Data on the 20 repair yards are not available, so it is not clear whether repair demand at these yards presses on capacity. Since much of the Navy repair work is accomplished in the eight active Navy shipyards, one can presume considerable idle capacity exists.

In all of this it must be kept in mind that considerable modernization of most of the 12 major yards has taken place, although only one of these shipyards--(Litton) Ingalls Pascagoula West Bank is of post-war design (as compared to most foreign commercial and some foreign government yards). It could be that the average keel-to-launch times in Table 3-6, which reflect the experience of the major yards, might not even approximate what would occur if some World War II yard which has built barges and drilling rigs for two decades were commissioned to construct a major naval combatant.

E. OTHER FACILITIES AFFECTING CAPACITY

As was mentioned in the early paragraphs, considerably more capital facilities are needed than a mere *place* to construct a ship and a means to get it into the water. Means are needed for storing and processing the steel shapes and plates that must also be formed into structural elements by cutting, bonding and welding; a source of forgings and castings for shafts, propellers, stanchions, bollards, padeyes, flanges, etc., (even perhaps a wholly-owned foundry on the shipyard premises) is needed; facilities and tools to store, process, and assemble all the parts that go into the finished ship must be present.

If building positions represent no serious obstacle to expansion, then these other facilities constraints, should they exist, could come in terms of the capacities of cranes; plate cleaning, cutting, and bending facilities; storage for materials and shapes; pipe bending machinery; automatic welding facilities; foundry and machine shop facilities. While [38] and [39] give

considerable detail about these facilities, their specific capacities are matters of construction demand and management of yards. There is no simple way to express limitations such as that which the lifting capacity of a crane places on the building position where it is employed. Should the crane have a lift limit, say 100 tons, it does not mean that a ship built of sections weighing 200 tons cannot be constructed--it would mean that it cannot be constructed off-site of 200 ton modules and *assembled* at the site--it must be *erected* at the site out of elements weighing 100 tons or less.

Without the resources to investigate such detailed matters, the study has chosen to be guided by the capabilities implied by NAVSEA assignments. The principle is as follows: if NAVSEA has assigned a specific type of ship to a specific yard (in any program), then that yard is assumed to have crane and materials handling capacity to build the ship--or any smaller ship. Thus this study has relied on the detailed facilities knowledge at NAVSEA. With some exceptions which are detailed in Chapter IV below, if a shipyard appears in the NAVSEA program as being capable of building a large combatant, then it is assumed to have the physical facilities to build any smaller combatant (auxiliary or merchant ship). If it is not assigned combatants by NAVSEA, but auxiliaries of a certain size, it is assumed to have facilities to build any smaller auxiliary or merchant ship. For those yards assigned only merchant ships by NAVSEA, it is assumed that some of the facilities to build auxiliaries and combatants are lacking. The effect of this may be appreciated by examining Table 3-9 which summarizes the capabilities. Available detailed information provided some spot checks which confirmed that no error seemed involved in our assumptions.

F. TWO SPECIAL LIMITATIONS

One factor that is of some consequence and would eliminate some yards from consideration for large submarines and some

large surface ships is the depth of water at the launching way or in the access channel to a roadstead (or in some cases the access from roadstead to open sea).[1] For the Great Lakes shipyards, the limit for an ocean-going ship is the maximum size that can be accommodated in the locks in the St. Lawrence Seaway.[2]

G. CAPACITY OF THE SUPPORTING INDUSTRIES

Again, with a caveat as to the possibility of a mismatch between the existing building position and materials handling and machining equipment and storage (all of which might delay ship construction in an idle dock), there seem to be plenty of docks and ways of sufficient size to accommodate a substantial increase in new construction. But these are of little use if the necessary material and parts, which are supplied by supporting industries, are not available in quantity and in "timely fashion." Since shipbuilding is not vertically integrated, as was discussed in Chapter II, it must depend on the wide variety of industries described. Here one must be careful to distinguish between the basic elements of a ship such as steel plate and shapes, boilers and turbines, parts and fittings of all kinds which are the responsibility of the shipbuilder, and those items of U.S. Navy equipment such as weapons, electronic warfare devices, nuclear reactors, special radars and so on which are procured and supplied by the Department of Defense. The shipbuilder's responsibility is to incorporate the latter into the ship's structure at the appropriate stage in construction.

[1]The access from Norfolk (and the Chesapeak Bay) to the Atlantic is via a channel which crosses a tunnel segment from the Norfolk to Cape Charles Bridge and tunnel with insufficient water depth to accommodate a Trident submarine. Currently, Navy CV and CVN are limited to 5 knots crossing the tunnel to avoid compression wave effects that might breach the tunnel walls.

[2]MARAD [38]. (730 feet by 78 feet).

Table 3-9. IMPLIED FACILITIES CAPABILITY: 40 YARDS (FROM NAVSEA ASSIGNMENTS OF ALTERNATIVE PROGRAMS)

Yard Class	Total Number	Combatants			Auxiliaries			Merchant		
		Large[a]	Medium[a]	Small[a]	Large	Medium	Small	Large	Medium	Small
Category I	9	1	5	7	2	7	7	3	4	8
Category II	5	0	1	2	4	5	5	2	4	4
Category III[b]	11	0	1	1	0	5	6	2	4	4
Other Private Naval Shipyards	11	2[c]	2	4	1	4	7	1	5	6
Naval Shipyards	4	2	2	4	0	0	0	0	0	0

[a]Large = 700 feet or more in length.

Medium = 475 - 699 feet in length.

Small = less than 475 feet in length.

[b]Four of the NAVSEA Category III yards are not assigned any US Navy or MARAD projects in the NAVSEA assignments of alternative programs.

[c]Assumes reactivation and private shipbui'er use of facilities at two former Naval Shipyards.

The latter problem, while it is a source of considerable argument between the Navy and its shipbuilders, will not be considered here. What is desired is an assessment of the likely bottlenecks in materials and parts which might develop in an expansion of shipbuilding demand. It is not possible to conduct a detailed analysis of the supplier situation, but some feel for the problem can be obtained from other evidence.

One indication of supply difficulties related to capacity is the order lead time for components. All other things being equal, current long lead times reflect either inadequate capacity, a practice of custom building (which means that production for inventory simply does not exist), or low priority to shipbuilders as customers. The last could be changed by direct action in an emergency.

The Navy maintains and updates data on lead times as an aid to planning for ship procurement.[1] The Navy distinguishes among three categories: Ship Components, Basic Materials, and Weapons/Electronics Components and Systems. The first category runs from "Air Conditioning Plants" and "Anchors" to "Winches" and "Windlass, Anchor, Electric/Hydraulic." The second covers "Aluminum Alloys, Castings" to "Steel-Carbon, Shapes, Structural, etc.,--Wide Flange Beams." The final category is a list extending from "Bus Cars" and "Buzzers" through such items as "AN/SPY-12, Search/Track Radar (Aegis)" to "Vertical Launch System, SSBN Launcher Control Group Trident-1/Poseidon." Such things as "Bus Bars" are contractor-furnished, but AN/SPY 1-A radar sets are government furnished equipment (GFE).

The lead times specified are described as approximating "the interval between the date a manufacturer accepts a firm order and the shipment date of the first complete production unit." They are listed for "Initi l/Order" and "Repeat Order," with the first allowing for designing and tooling and testing

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[1]NAVSHIPSO [44].

for a first-time specification, the second merely the resumption of production (tooling being existent) after a complete break in production. Both of these times could be much longer than the time from order to shipment for an in-production item. As a measure of potential capacity limits, one would do better to examine the "repeat order" lead times. For listings by categories, the distribution of item lead times is shown in Figure 3-3.

The distributions for "ship components" and "weapons/electronics..." are quite similar with an overall average of about 12 months. In the basic materials category, however, a fairly large fraction of the items appear to require order lead times beyond 30 months, suggesting capacity problems. The specific long-lead items in each category are revealing.

In the component category, the lead times exceeding 24 months are confined to "Turbines, Main Propulsion, Nuclear"--24-28 months; "Turbines, Main Propulsion, Gas, Nominal/20,000 SHP"--34 months, and "Gear, Reduction, Main Propulsion, Nuclear"--24-28 months[1] These would affect primarily CVN or CV and the CGN and SSN programs. Given the long building times--47 months for SSN--for these ships, the problem would appear to be one of timely ordering.

The long-lead electronics-weapon systems are radars, sonars and navigation electronics that are to some degree still under development. One of the longest, "RAM Missile System"--36 months, is a new missile not yet approved for volume production. The problems here, as mentioned, are primarily GFE questions and are not under shipbuilder control. However, late deliveries of GFE can result in delays in construction and increased cost to the shipbuilders.

The longest lead times in the area of basic materials are aluminum plate, structural shapes and tubing, which require

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[1] *Ibid.*, p. A.

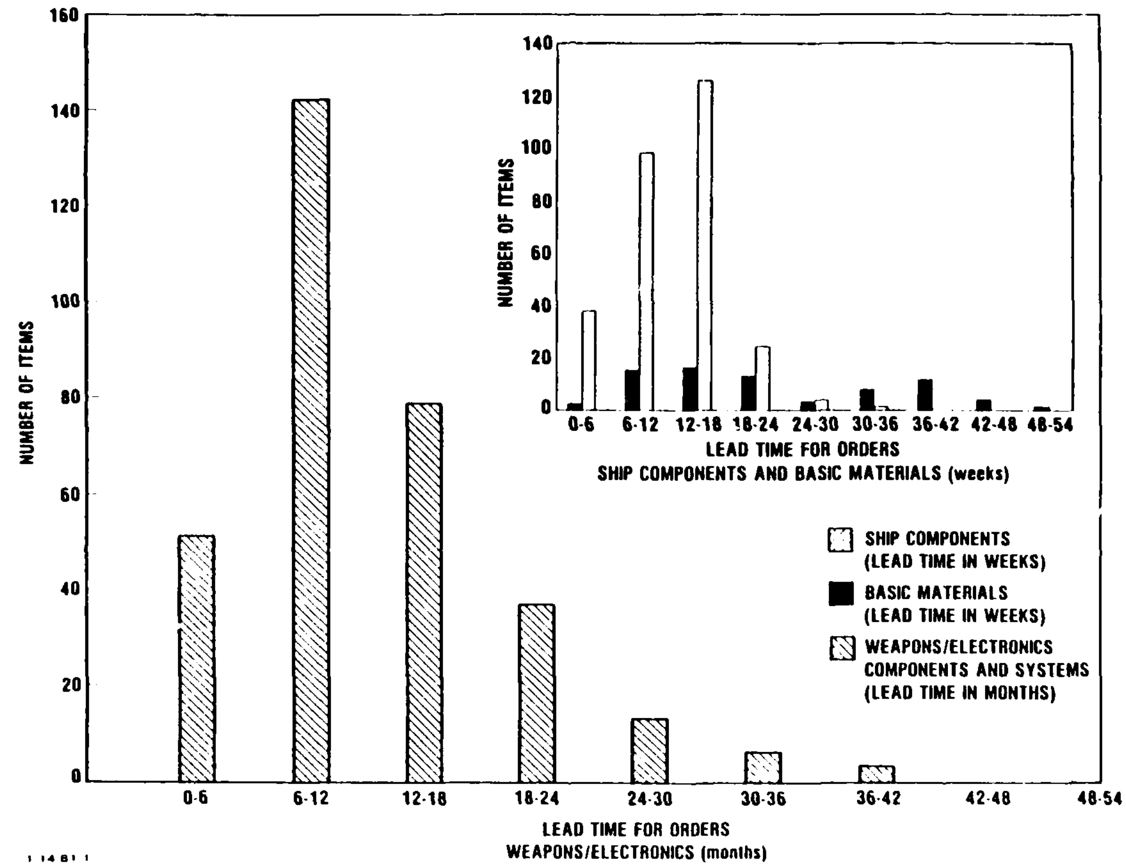

Figure 3-3. CURRENT (1980) LEAD TIMES FOR SHIPBUILDING COMPONENTS

38-44 weeks from order to delivery. The reasons for the delays here have to do, in part, with competition with the aerospace industry. The shipbuilding industry is only a minor customer for aluminum alloy fabrication. Another odd item is lumber and wood products, where 36-56 week trends are recorded.[1] Here again the evidence suggests this is not a bottleneck item, but reflects industry practice of cutting and curing after order receipt, especially for valuable hardwoods such as oak for planking and decking.

The other long-lead time basic materials are forgings and castings of aluminum, copper and steel. This is an avowed bottleneck and an obstacle to expansion. Foundry products of large size are still produced by individual craft methods, and the number of foundries has been steadily declining.[2] Small metal forgings and castings are mass produced by new automated techniques using powdered metals, largely for the aircraft industry.

Shipbuilders also report long delays and uncertainties in certain classes of valves,[3] even though NAVSHIPSO lead times do not reflect this.[4] But the impression one gains from studying industrial directories is that the number of valve manufacturers is quite large. What may be the case, however, is that shipbuilders are not major customers, since valves are items in almost all manufactured machines and appliances as well as in almost all structures. This leads

[1]See Table 3-10 below for the fraction of total demand.

[2]A study relating contraction in the iron foundry industry to health and safety regulation is Brumm, H.J. *Erosion of the Defense Industrial Base*, October, 1977, IDA P-1301.

[3]Conversation with authors, 1980.

[4]The NAVSHIPSO list is avowedly incomplete with regard to valves, which are not only numerous but highly specialized devices in marine applications. According to D.M. Mack-Forlist, specialized sea-water valves are manufactured by only a few firms using special alloy materials sometimes difficult to obtain.

to another measure of the likely industry response to increased shipbuilding demand.

It is more or less a truism that market-oriented private businesses respond first to their largest customers. Some partial data on shipbuilder (and ship repair) use as a fraction of total industry output in some of the fields mentioned is informative. The most recent Census of Manufactures provides data making it possible to estimate shipbuilding usage as a fraction of industry output for certain materials.[1] Table 3-10 below shows the results.

Except for steel plates, where the shipbuilding industry used almost 17 percent of industry output, steel structural shapes with 4.5 percent and steel castings with 2.1 percent, shipbuilding as an industry is a minor customer of the metal and metal products industries. However, for some specialized alloy steel plates such as HY80 for submarine hulls, the shipbuilders are almost the only users. The firms in the industrial base capable of *and interested* in such specialized production have dwindled to one or two,[2] so that a several fold expansion of submarine construction might involve lead times considerably in excess of the current NAVSHIPSO figure of 20 months for such alloy plate.

The conclusion from the discussion in Chapter II above of the behavior of lead-times over economic contraction and expansion periods is that shipbuilding is not in a position to command rapid responses by suppliers. The industry is not important enough to most suppliers and may have to depend upon government priorities to secure timely deliveries in a competition with other users. This sort of bottleneck might not manifest itself except when all industries were expanding--as

[1]Reference [32].

[2]R. Gilmer, [7].

Table 3-10. SELECTED MATERIALS CONSUMED BY SHIPBUILDING AND REPAIRING AS A PERCENTAGE OF SUPPORTING INDUSTRIES' OUTPUT

Source: 1977 Census of Manufactures
s = too small to report, C0.1%

	1977		1972	
	% QUANTITY	% VALUE	% QUANTITY	% VALUE
CARBON STEEL				
Bar & Bar Shapes (excluding concrete reinforcement)	0.6%	0.6%	1.3%	1.2%
Sheet & Strip	s	s	s	s
Plates	16.7%	16.6%	15.2%	17.0%
Structural Shapes	4.4%	4.7%	5.3%	5.6%
Wire and Wire Products (excluding fencing)	0.2%	0.3%	0.2%	0.2%
ALLOY STEEL (finished)	0.3%	0.4%	0.3%	0.5%
STAINLESS STEEL				
Sheet & Strip	NA	0.2%	0.1%	0.2%
All other shapes and forms	0.6%	0.5%	0.7%	0.6%
COPPER				
Rod, Bar & Shapes	NA	0.1%	0.1%	0.1%
Plate, Sheet & Strips	0.2%	0.3%	0.1%	0.1%
Pipe and Tube	1.5%	0.9%	NA	1.6%
ALUMINUM				
Sheet, Plate & Foil	0.4%	0.3%	NA	0.2%
Extruded Shapes	NA	0.6%	NA	0.2%
All other	0.1%	0.1%	0.1%	0.2%
CASTINGS				
Steel (excluding investment castings)	0.6%	0.6%	0.5%	0.5%
Aluminum (excluding kitchenware)	0.2%	0.1%	s	s
Copper (excluding bearings)	0.4%	0.3%	NA	NA
ENGINES				
Diesel & Semidiesel, non-automotive	NA	0.3%	NA	0.2%
DRESSED LUMBER	0.1%	0.3%	0.1%	0.2%
PLYWOOD	NA	0.5%	NA	0.2%
PLASTICS				
Sheet, rods, tubes, shapes	NA	0.1%	NA	NA
RUBBER				
Fabricated (excluding tires, tubes, hose, bolting, gaskets)	NA	0.1%	NA	NA
SCREW MACHINE PRODUCTS	NA	0.6%	NA	NA
ENGINE ELECTRICAL EQUIPMENT (magnets, generators, spark plugs, etc.)	NA	0.7%	NA	NA

in a mobilization effort. A detailed analysis of the shipbuilding support industries to ascertain their other defense or defense-related customers would be required to quantify the problem much further.

One informal estimate of the state of the shipbuilding support industry can be obtained by considering the number of US producers for specialized marine products, as listed in the standard industrial directory.[1]

As one can see from Table 3-11, the US firms supporting the shipbuilding industry are, on the whole, a minority in a world-wide industry. The principal exception is in the gas and steam turbine generator industry--which supplies on-shore power generation as well as shipbuilding. The listings, of course, do not represent a census of industry; they reflect an interest in international sales by the listed firms.

However, recent representations by the US foundry industry[2] urging, among other measures, restriction of overseas procurement of forgings suggest that the preponderance of shipbuilding-oriented support firms in Europe and Japan may well discourage aggressive development of such business in the US by US firms--since export possibilities would not seem bright.

H. EXPANSION CAPABILITIES OF SUPPORT INDUSTRIES

In Chapter II, the time pattern of order lead times was shown to be quite variable, and seemingly cyclical; that is, increasing during periods of expanding economic activity and shortening as business slowed down. What might happen to increase order lead times for an expanded program of shipbuilding

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[1]Grady Cole, [3].

[2]Reference [6]. According to this press release, only 1/3 of the forging industry input of labor hours is used in military forgings of which aerospace products take three-quarters. Thus, shipbuilding must be some fraction less than 8% (1/4 x 1/3 = 1/12).

Table 3-11. U.S. SHIPBUILDING SUPPORT FIRMS

Component Category (NAVSHIPSO) and ISSD	No. of US Firms Listed	European & Japanese Firms Listed
Air Conditioning Plant	3	26
Anchors	0	15
Bearings, Stern Tube (Large)	1	15
Bearings, Thrust (Large)	1	14
Boilers, Auxiliary	3	18
Boilers, Main	5	14
Cable, Electric	3	28
Chain, Anchor	1	20
Compressors, Air	4	34
Condensers	1	11
Consoles and Control Equipment, Bridge	3	24
Consoles and Control Equipment, Central	4	26
Cranes, Deck	3	24
Gears, Reduction	4	24
Generator, Electric, Diesel	3	51
Generator, Electric, Gas Turbine	4	7
Generator, Electric, Steam Turbine	2	6
Hydraulic Power Equipment	1	22
Motors, Electric	5	29
Propellers, Fixed Pitch	1	20
Propellers, Controllable Pitch	1	25
Pumps, Fuel Oil	5	23
Bilge	2	23
Lube Oil	2	20
Sewage Treatment, Equipment (Package Unit)	4	17
Steering Gear	1	17
Switchboards	4	52
Valves	2	118
Winches	4	33
Windlass	2	26
Subtotal All Categories-Unique Firms	(50)	(nid)
Engines, Diesel		
Above 750 thru 1600 BHP	6	66[b]
Above 1600 thru 3600 BHP	4	32[c]
Turbines, Main Propulsion		
Gas	4	
Steam-Non-Nuclear	3[a]	

[a]Includes one shipbuilding firm.

[b]Source: Reference [10].

[c]Includes 11 shipbuilding firms.

would lead also to increased demand for other defense goods. Unless the US economy started from the kind of slack position of the late 1930's, capacity of all industry would likely be rapidly reached. What might then happen, without controls and priorities, perhaps can be inferred by examining the relationship between industrial capacity utilization and NAVSHIPSO order lead times.

In Figure 3-4 below some of the order lead times series' of Chapter II have been plotted against the FRB industrial capacity utilization index, lagged one year.

What the figure suggests is that order lead times are strongly affected by the pace of industrial activity. Rates of capacity utilization above 80 percent seem to be associated with major swings in order lead times for basic steel and aluminum fabrications. But lead times for such items as main reduction gears and gas turbines appear unrelated to capacity utilization rates. Not plotted here are other items from the series in Chapter II, but they show the same kind of behavior. What appears to be the case is that for those items in which capacity is shared with other users, shipbuilding moves to the end of the queue as capacity is approached; but for shipbuilding specialty items, apparently there is unused capacity even when manufacturing in general begins to be taxed to meet demand. At least such an hypothesis is consistent with the data.

What this could mean is that without priorities shipbuilding expansion would be hindered by increasing delays in deliveries of components. Clearly more detailed investigation would be needed to confirm and specify the industry by industry application of such an idea.

Another area which needs investigation as to the constraints that might manifest themselves has to do with GFE and GFM. The weapons systems, defensive electronics and

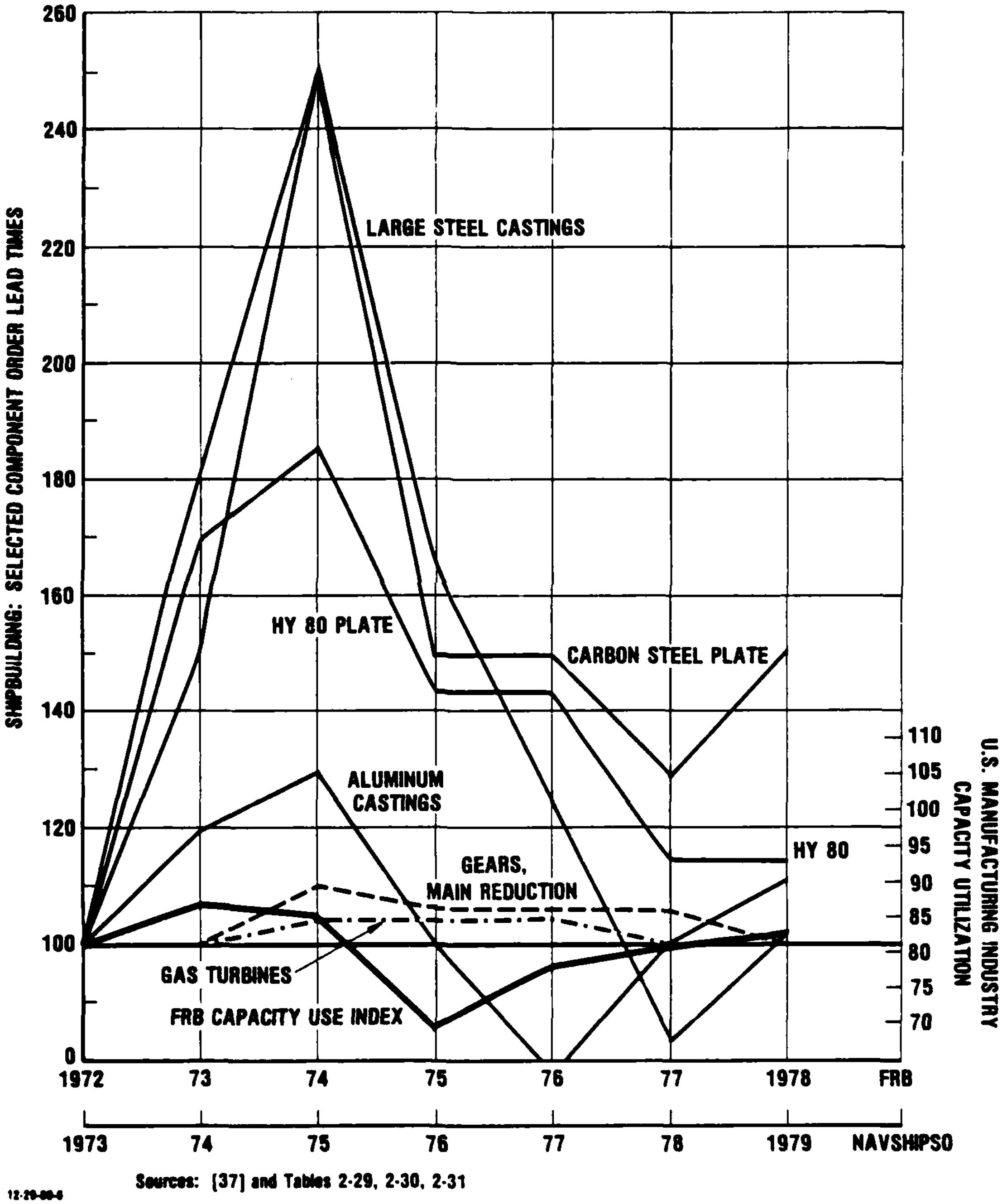


Figure 3-4. U.S. MANUFACTURING CAPACITY USE AND ORDER DELAY TIMES

command and control hardware that go into a modern combatant are produced by an industry that faces rapidly growing commercial demand for its product. Since the ship-application devices and systems are relatively complex, expensive, and involve comparatively few installations (tens and twenties instead of thousands and hundreds of thousands) it is difficult to envision suppliers investing to accelerate production that will total only a few units at the cost of reducing commercial business. In short, the industry in a completely uninfluenced environment is likely to adjust its specialized system capacity to expected low-rate procurement--certainly not to aim at producing AEGIS electronics suites for speculative inventory. Thus a program to expand the number of complex combatants might have to contemplate subsidizing an acceleration in important areas of GFE, or accept as the ship production limit the existing component production rate as determined by industry profit considerations. Again, these generalizations stress the need for specific studies in specific supplying industries. The order times cited earlier, however, tend to support the supposition that low-rate, low-risk is the industry approach to advanced technology components for the Navy.

I. ADDITIONAL EVIDENCE ON INDUSTRY CAPACITY.

Despite the existence of unused capital facilities and putting aside the possibility that shipbuilding component suppliers may be the earliest constraint, there is evidence of what might be expected to happen in the face of a surge in demand. The past experience with what is called "slippage" provides some insight.

In a preceding study[1], the "slippage" experience of commercial shipyards constructing Navy ships was studied in detail. "Slippage", which represents failure to meet contract

[1] Naval Ship Procurement Process, [2].

or planned event completions--of which delivery of the completed ship is the most serious--measures two not necessarily unrelated factors. In one sense, slippage represents the inability of the Navy planners and the contracting shipyards to correctly anticipate the time required to complete the various phases of ship construction as a simple scheduling problem. The other aspect of slippage could represent the result of exceeding the capacity of the shipyard to perform the work either through lack of manpower or facilities. The following table, Table 3-12, shows recent actual slippage experience for ships delivered after 1976 compared against the most recent Navy planning factors, as well as the ones used when the contracts were let.[1] While the planning process has moved toward more realistic predictions, the last column shows that it lags behind the actual deterioration in production rates.

It appears that the "pre-construction interval" factors are relatively useless as a measure of anything relating to resource use. For a series such as the 27 DD 963's built at Ingalls with an average pre-construction interval of 49 months, the actual award to start date varies from 23 months for DD 963 to 77 months for DD 989.[2] Thus the "slippage" of interest is that which relates to construction intervals.

Of the intervals shown in the table, the "K-L" or keel-to-launch interval, represents the period during which the project occupies a building position. The "L-D" interval is roughly the period during which the ship occupies a position at a fitting dock. The "S-K" or start of construction to keel laying period represents a time during which various forms of processing of materials and fabrication of elements to go into the construction of the ship can take place. The exact point in time at which a particular part of the ship may be fabricated and installed can vary. As a test of this, some recent Navy data on construction

[1]Source: NAVSEA, not strictly comparable with 2-9, 2-10.

[2]These data from NAVSEA detailed computer summaries of performance.

Table 3-12. RECENT SLIPPAGE EXPERIENCE FOR SELECTED PROJECTS (Deliveries in 1976 and later (except for CVN 68 in 1965)

Shipyard Hull Number	Using 1980 Planning Factors Versus Experience													Using Contract Planning Factors
	Pre-Construction Intervals			Construction Intervals										
	Planned	Actual	Total Slippage	Planned				Actual				Total Slippage	Total Slippage	Total Slippage
	A-S	A-S	A-S	S-K	K-L	L-D	Total	S-K	K-L	L-D	Total	S-D	A-D	A-D
Electric Boat														
SSN 690	12	6	-6	14	23	18	55	13	26	32	71	16	10	[illegible]
SSN 692	12	6	-4	14	23	18	55	15	37	25	77	22	18	28
SSN 694	12	8	-4	14	23	18	55	22	38	20	80	25	21	27
SSN 696	12	8	-4	14	23	18	55	14	42	20	76	21	17	31
SSN 697	12	14	2	14	23	18	55	18	33	29	80	25	27	[illegible]
Newport News S.B.-DD.														
SSN 691	12	15	3	14	23	18	55	13	34	20	67	12	15	26
SSN 693	12	19	7	14	23	18	55	19	34	16	69	14	21	27
SSN 695	12	15	3	14	23	18	55	23	30	14	67	12	15	28
CVN 68	12	7	-5	14	43	25	82	7	47	35	89	7	2	19
CVN 69	12	-5	-17	14	47	25	82	6	62	23	91	9	[illegible]	[illegible]
CGN 38	16	1	-15	8	22	20	50	7	28	21	56	6	-9	15
CGN 39	16	8	-8	8	22	20	50	11	24	24	59	9	1	15
CGN 40	16	21	3	8	22	20	50	15	17	24	56	6	9	21
Ingalls														
27 DD 963 (Avg.)	55	49	-6	4	15	15	34	7	15	20	42	8	2	[illegible]
Bath														
FFG 7	18	14	-4	8	8	12	28	5	15	15	35	7	3	5
FFG 8	18	19	-9	8	8	12	28	13	10	13	36	8	-1	2
Todd														
FFG 9	18	11	-7	6	8	15	29	5	12	20	37	8	1	1
Lockheed														
AS 39, 40 (Avg.)	12	9	-3	4	17	16	37	7	18	22	47	10	7	7
National Steel														
LOR 7	12	10	-2	5	17	12	34	3	11	22	36	2	0	6

Source: 1980 NAVSEA Data

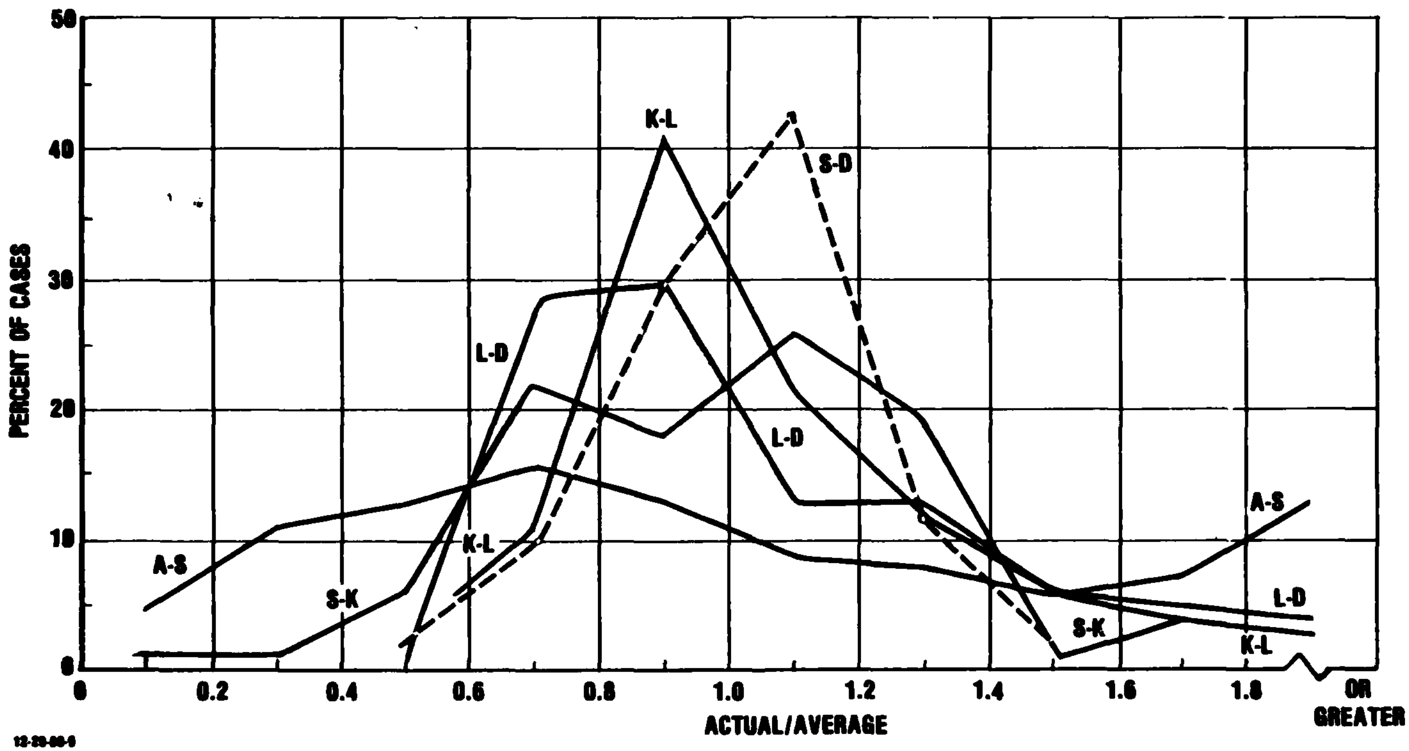
A-S: Award of contract to start of fabrication.
S-K: Start of fabrication to laying of keel (actual occupation of building position).
K-L: "Keel-laying" to launch.
L-D: Launch to delivery of completed ship to Navy.

intervals were analyzed for combatant and non-combatant ships completed in the 1970's. The results are shown in graphic form.

In Figures 3-5 and 3-6, we show the distribution of interval times for the various classes of ships about the average for each class. If there were no "slippage," that is to say variation from one example of each ship type to another, then each interval, say "S-K" for each example of a given ship type would be the same and there would be no variation except for what was due to random influences. The actual intervals would then be distributed about the average in the familiar normal curve. When we examine Figure 3-5 for combatants, it is clear that only the keel-to-launch (K-L) intervals show such a distribution, but the overall *physical* building periods are distributed in such a fashion, skewed a bit to the high side. What this suggests is that the overall building time ought to be predictable.

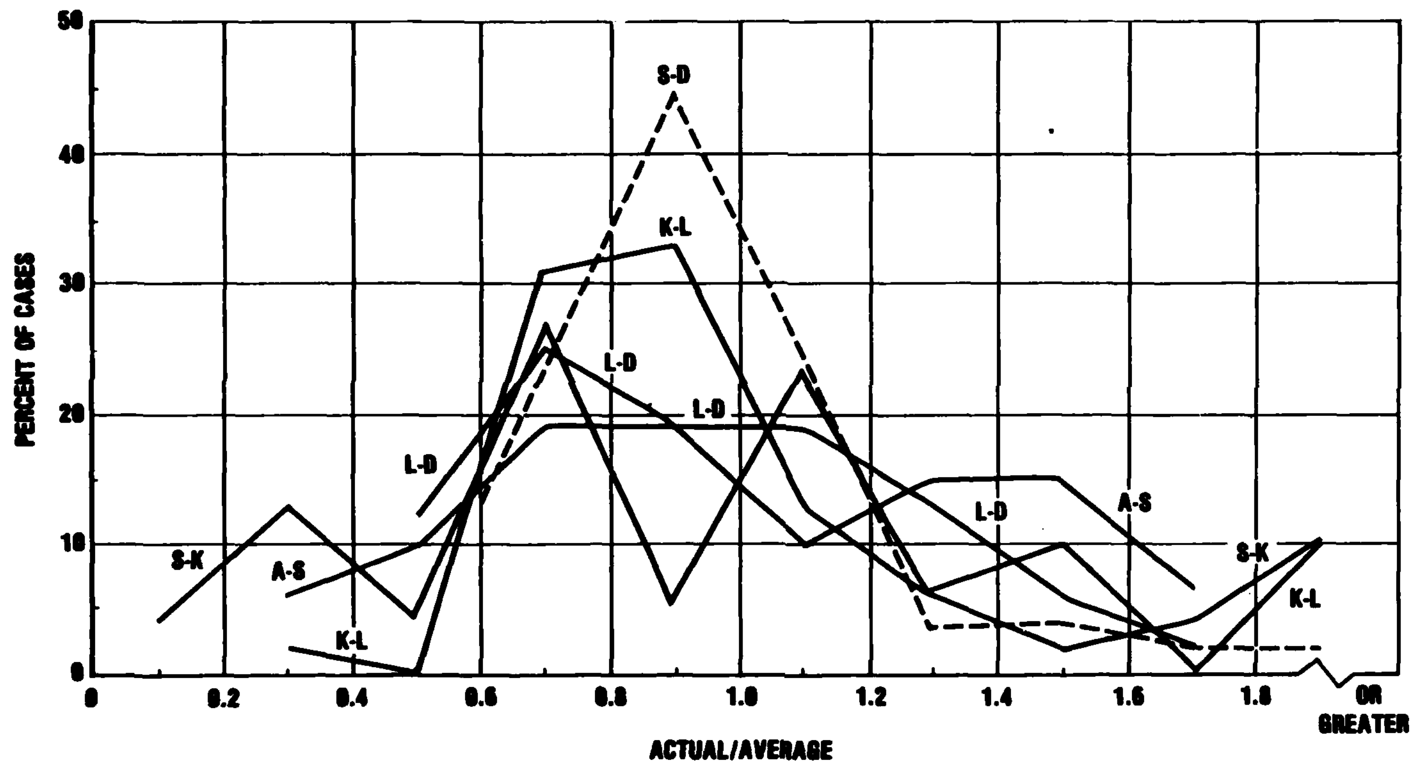
The results for support and auxiliary ships in Figure 3-6 tend to support this inference. The wide variation about the average for each specific construction interval becomes a nearly normal distribution when all intervals from construction start to delivery are combined. When one reflects on how this might come about--namely that delays and accelerations in each interval tend to be offsetting--it does not take much imagination to hypothesize that the "intervals" are fairly arbitrary benchmarks in an overall process and that a shipbuilder might (for whatever reason) delay laying the keel beyond the "normal" interval, but use the time to fabricate elements and organize his effort in such a way as to shorten the time of construction on the building way.

As most shipyards assemble ships from modules, "start," "keel-laying," and "launch" may have quite different meanings, as far as progress toward completion, than the same events



A-S: Award of contract to start of fabrication.
S-K: Start of fabrication to laying of keel (actual occupation of building position).
K-L: "Keel-laying" to launch.
L-D: Launch to delivery of completed ship to Navy.

Figure 3-5. VARIATION OF CONSTRUCTION INTERVALS: COMBATANT SHIPS (86 Ships)



A-S: Award of contract to start of fabrication.
S-K: Start of fabrication to laying of keel (actual occupation of building position).
K-L: "Keel-laying" to launch.
L-D: Launch to delivery of completed ship to Navy.

Figure 3-6. VARIATION OF CONSTRUCTION INTERVALS: SUPPORT SHIPS (52 Ships)

once had in a traditional yard. Theoretically, a ship could be completely fitted out and ready for trials as soon as it slides into the water at launching. Typically, and sometimes because of structural constraints such as overhead crane clearances, the taller elements of a ship's superstructure are not constructed until after launching. But with modern modular construction the degree of completion at any "stage" can be varied considerably.

J. CONSTRUCTION TIME AND "LEARNING"

The analysis of construction times permits comment on another possible source of industry expansion, namely the learning effect that *might* come with longer series production possible in an expanded building program. In Chapter II, the results of studies of merchant ship costs were discussed, the tentative conclusion being that only small "learning" effects were apparent. In the absence of a study of costs of naval ships one can use construction time as a surrogate, the argument being that the cost savings, as manifested in reduced labor input, would show up in part as reduced construction time. A look at overall "award to delivery" times for series ships in the NAVSEA data for recent deliveries suggests the opposite, but this is owing to the practice of counting series awards from the same date, even though later ships are not intended to be started for years after that date. One can avoid this problem by examining the data on actual construction activity, as is shown in Table 3-13 below, for the DD 963 series.

At first glance it would appear that the first and last ships took the same time to build. However, if one should look at the "keel to delivery" data, the experience on the last 8 ships suggests that some sort of "learning" could have been involved. If "construction time" were substituted for cost in the learning curve equation discussed in Chapter II

Table 3-13. SERIES "BUILDING" TIMES, LITTON/INGALLS DD 963 CLASS

Hull by Order of Start Date	Elapsed Time: Months Award to Delivery	Elapsed Time: Months Start to Delivery
1	38	33
2	39	36
3	40	38
4	43	38
5	43	41
6	44	39
7	40	38
8	43	38
9	42	38
10	45	38
11	48	39
12	51	40
13	34	30
14	37	32
15	37	34
16	40	36
17	40	37
18	42	37
19	42	37
20	45	39
21	44	35
22	45	33
23	45	32
24	47	32
25	45	30
26	47	30
27	39	29

above, the decrease in construction time for the last 8 ships would be consistent with a 91% learning curve. An examination of three other long series-- 14 "Knox" class FF's at Avondale, 7 FF's at Todd, 15 LST's at NASSCO--shows a similar effect if the "keel to delivery" interval is used. Figure 3-7 shows the building time for successive ships as a fraction of the first (or second in some cases) ship's building time and the 95%, 91% and 89% learning curves. To the extent that "building time" and cost are related, these naval ship results seem to suggest that the likelihood of series production reducing costs in naval shipbuilding is not any greater than in merchant shipbuilding. Whatever efficiencies arise seem to be largely realized by the fifth or sixth ship in a series.

Even if the relation between time and cost is not established, a weak effect of "learning" in reducing the construction time for series ships has important consequences for planning for expansion. It implies that the Navy planning factors for construction times - even if they are based on short series results - predict accurately times for the long series that might come with an expansion in building. Thus if capacity to expand appears to be limited using the planning factors and existing facilities, one cannot expect "learning" to offset this. Increasing facilities or labor force inputs will still be necessary to expand the rate of output.

K. EMPLOYMENT AND CAPACITY

The lengthening of the construction period in a yard, when it occurs, could be due to a lack of capital facilities (which was indicated as not likely for most of the major yards at current loadings); a delay of materials or equipment (which is again not likely in recent experience except for very bad planning); poor management (for which few objective measures are available); or not enough labor of the appropriate

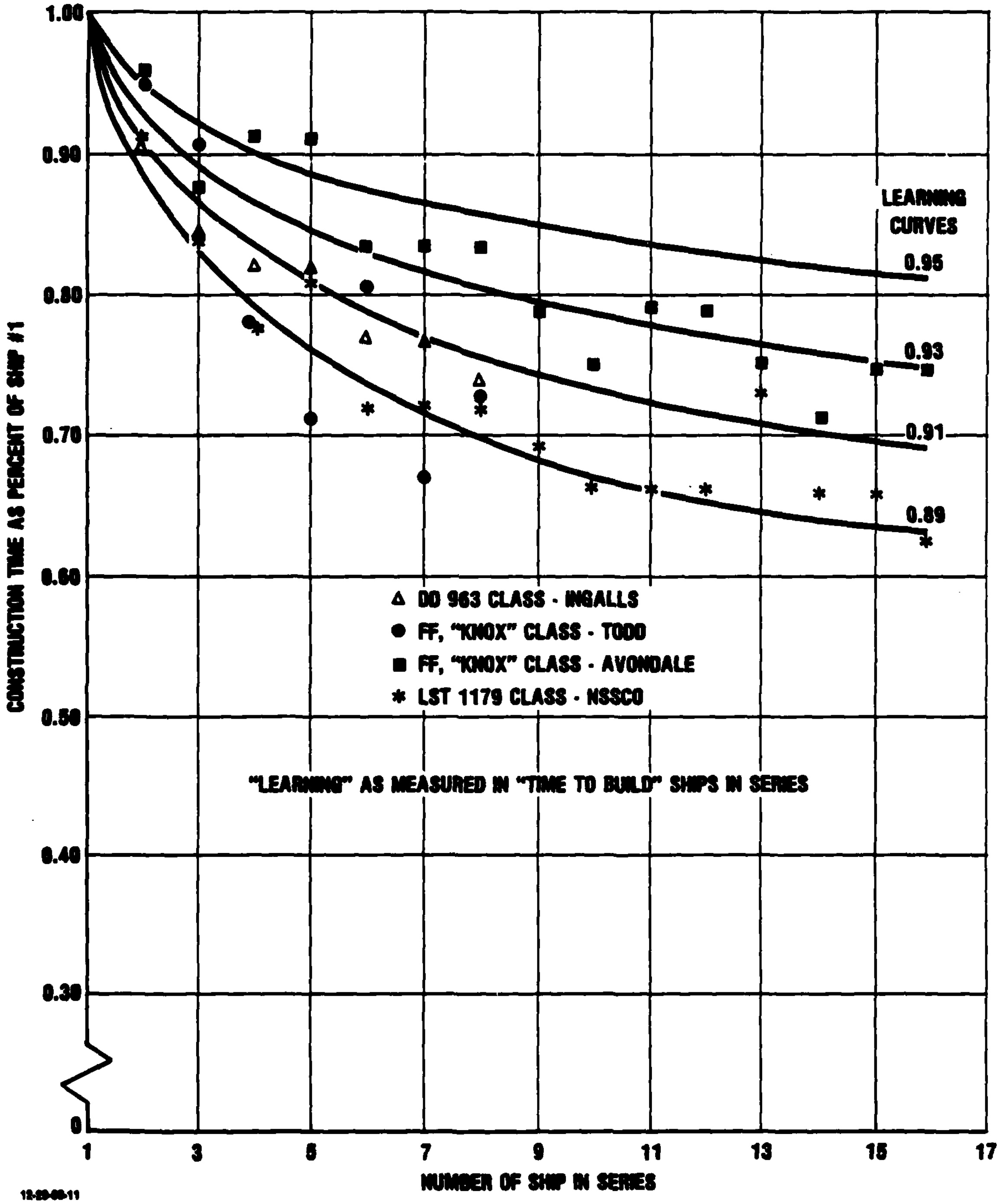


Figure 3-7. "LEARNING" AS MEASURED IN "TIME TO BUILD" SHIPS IN SERIES

skills to efficiently utilize the plant or meet the construction schedule pace of work. As has been discussed in the preceding chapter, there appears to be no overall shortage of labor within the regions of major yards, although some time would be involved in expanding certain skill groups, because of training. The problem of expanding the labor supply will be taken up later, but some measures of nearness to capacity can be noted.

Table 3-14 below presents the recent employment history of 11 major shipyards, along with the Navy estimate of "Potential Mobilization" employment, which represents "capacity" in some sense. Note that, of the major yards, only Ingalls, Electric Boat and Newport News were operating at above 50% of their potential, with the whole industry at something less than 50%. What is striking is that our earlier count of the percent of building positions filled was 58%. Thus one might guess that a doubling of shipyard activity would be possible on both the facilities and labor side. This might or might not be equivalent to doubling the rate of ship output, however.

One authority has suggested that doubling the labor force in a shipyard, *if accomplished over two years,* would result in an increase in output for those two years of perhaps 55% to 60%.[1]

Just how long it would take to double the labor force at a yard is not a statistic routinely reported. It is really a question of labor supply conditions in a particular region, by skill group as is discussed in Chapter II.[2] While, as has been indicated, two years is a feasible period to double the force as a *management* rather than a labor supply matter, the question is more complex. If the surge of activity for

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[1] D.M. Mack-Forlist, correspondence with the authors.

[2] See especially pp. 2-46 to 2-48 above.

Table 3-14. RECENT EMPLOYMENT HISTORY: 11 CATEGORY 1 YARDS

SHIPYARD	MOBILIZATION POTENTIAL	1973	1976	1978	1980	1980 AS % OF POTENTIAL
Avondale	18,000	7,100	6,600	6,200	7,300	40.6
Bath Iron Works	12,000	2,200	3,400	4,500	5,300	44.2
(Sparrows Point) Bethlehem Steel	15,500	3,200	3,200	3,400	2,300	14.8
GD Elec. Boat	30,000	11,200	27,600	22,000	22,300	74.3
GD Quincy	24,000	4,300	4,300	6,000	4,900	20.4
Ingalls	21,000	17,800	24,700	20,800	17,000	81.0
Lockheed	6,600	1,500	2,900	3,000	2,300	34.8
Nat'l. Steel	16,800	2,700	6,500	5,400	6,400	38.1
Newport News	38,000	26,800	23,700	25,000	22,400	58.9
Todd, San Pedro	8,000	1,200	2,000	2,600	2,900	36.2
Todd, Seattle	7,200	600	800	2,200	3,300	45.8
TOTAL	197,100	79,100	105,700	101,100	96,400	48.9
% OF POTENTIAL	100.0%	40.1	53.6	51.3	48.9	

Sources: [20] and [38].

which the additional labor is needed involves a change in the product mix, additional problems of redirection and training arise. According to Mack-Forlist:[1]

> "There would be problems resulting from the changes in the mix of craft skills required when switching from one type of ship to another. Roughly, the skill compositions for the major principal programs are as follows:

	Tankers, Bulk Carriers	Complex Cargo Ships	Naval Auxiliaries	Aircraft Carrier	Nuclear Cruiser
Hull crafts	65%	55%	45%	25%	20%
Machinery & Outfitting Crafts	35%	45%	55%	75%	80%

> Without a force increase, a switch from tankers and other merchant ships to naval auxiliaries would involve the lay-off and hire or retraining of 10%-20% of the labor force. A switch from auxiliaries to combatants would involve similar numbers. The definition of hull vs. machinery and out-fitting crafts varies slightly among yards, but the above provides some measure of this aspect of the surge requirements."

Some insight into the possibility of recruiting enough workers to meet surge demand can be had by examining the past history of changes in the volume of shipyard employment. Presumably, if a shipyard has been able in the past to expand its labor force by, say, up to 20% per quarter and 50% per year, then it might be able to duplicate such a performance in the future. Table 3-15 shows some series' on recent employment trends in several of the regions in which shipbuilding firms are located.

The sustained maximum shipyard labor expansion rates vary from 13.2% per year for the 1965-1966 period in the Seattle-Tacoma area to 53.6% per year in the Gulf region in 1964-1965. These expansions were in response to relatively small surges in shipbuilding demand under peacetime conditions. It was the

[1]Correspondence with the authors.

Table 3-15. SHIPYARD EMPLOYMENT EXPANSION DATA BY REGION

Regional Employment and Expansion Rates (%) - 3rd Qtr. to 3rd Qtr.

Year	Northeast	Mid-Atlantic	South Atlantic	Gulf	California	Seattle-Tacoma
1964	20,233	19,267	36,267	10,767	25,367	12,433
1965	22,800(12.7)	20,433 (6.1)	35,200	16,533(53.6)	26,033 (2.6)	13,633 (9.7)
1966	25,533(12.0)	21,600 (5.7)	37,800 (7.4)	15,633	30,167(15.9)	14,000 (2.7)
1967	29,133(14.1)	21,600	41,800(10.6)	16,400 (4.9)	32,833 (8.8)	13,867
1968	28,100	22,367 (3.5)	42,433 (1.5)	20,300(23.8)	35,667 (8.6)	13,600
1969	26,667	21,800	39,733	20,033	35,633	13,167
1970	24,233	19,367	35,967	22,767(13.6)	30,567	12,633
1971	21,300	17,967	38,500 (7.0)	25,500(12.0)	27,633	10,667
1972	19,167	18,100 (0.7)	42,033 (9.2)	27,933 (9.5)	25,367	9,567
1973	10,100	19,333 (6.8)	41,500	26,967	19,533	10,367 (8.4)
			Maximum 12 Month Rate			
Rate	14.1%	20.5%	17.3%	53.6%	15.9%	13.2%
Period	(66Q3-67Q3)	(65Q1-66Q1)	(71Q1-72Q1)	(64Q3-65Q3)	(65Q3-66Q2)	(65Q3-66Q2)

Source: Neil S. Weiner, *et al.*,[47] and Harry Williams, *et al.* [50].

authors' judgment that an expansion rate of 25% per year overall represented a reasonable planning objective and should be achievable under normal peacetime hiring procedures, given sufficient shipyard orders to justify the investment in the necessary training for the more demanding craft skills. Because the shipbuilding industry appears to be a less preferred occupation for some skill groups, as discussed in Chapter II, if an overall economic expansion should occur at the same time as a surge in shipbuilding demand, the 25% labor expansion rate might not be so easily achievable. Under some circumstances, awardings of ship contracts, given an expansion of naval building, might have to take regional labor market conditions into account if high tonnage completion rates were desired. Some of the results of varying the labor expansion rate can be seen in Chapter IV.

L. SUMMARY

While the significance of the various potential limits on shipbuilding capacity as discussed above cannot be determined without more research, certain tentative conclusions can be hazarded. Each of them is elaborated in varying degrees in the sensitivity analysis of Chapter IV. They are:

1. Physical capacity, as measured by ways, docks, etc., of the industry appears adequate to a much higher level of naval and commercial building. In fact, substantial excess capacity may exist, as the next chapter will quantify, for all but nuclear powered ships.
2. Given sufficient lead time, say at least four years, the shipbuilding labor force could be expanded and trained to undertake any building program analyzed in the study.
3. Shipbuilding support industries cannot be counted on to respond to large demand increases without special incentives or allocations. This is largely

because of the relatively small size of shipbuilding demand in each support industry's total customer picture.

4. The system by which planning and contracting for naval ships is performed may lack sufficiently accurate predictive capability to manage a large expansion in building, although some elements are more reliable than others. Accurate predictions as to actual "building" time seem possible, for instance.

5. The existence of any great potential for reduced costs or more rapid production because of longer series production in an expanded naval building program is doubtful on the evidence. Type specialization yard by yard, as in the Soviet shipbuilding industry, would seem to have fairly limited benefits as far as increasing capacity or reducing costs in the U.S. shipbuilding system.

Chapter IV

U.S. SHIPBUILDING INDUSTRY FACILITIES AND TIME REQUIREMENTS FOR FOUR NAVAL PROCUREMENT PROGRAMS

A. INTRODUCTION

The major question confronting national security policy makers with respect to the U.S. shipbuilding and repair industry is the capability of its relevant sector to provide a sufficient production base for the nation's maritime posture. The term "sufficient" must be defined within the context of an envisioned hypothetical need; by its nature it is a relative rather than an absolute standard. That fact enforces on the study specific interpretations of our tasks, choices in methodology, and definitions of concepts that must be made clear at this point.

This chapter analyzes the sufficiency of the U.S. shipbuilding industry as a procurement base under conditions of "surge demand" in a "contingency mobilization." These terms are meant to connote a significant acceleration in the demand for naval and merchant ships over a 10 or 15 year period of heightened international tension short of war or full-scale mobilization. It may or may not be accompanied by a simultaneous surge in demand for other weapons systems, and, despite the rather extensive period provided for the build-up, the study interprets the motivating forces behind the demand to place some premium upon shortening that time period if possible.

Within that time frame of perceived need, what determines the size of the build-up that should be used to judge the adequacy of the present industrial base? Before a complete analysis

can be conducted, policymakers must decide the size and makeup of this maximum program which the industry must be able to complete. The maximum program then becomes the benchmark against which the shipbuilding industry's potential is measured.

This study was not able to make such a determination of a maximum surge demand program, since that is a matter of policy. Rather, four programs were used that appeared to bracket feasible demand choices over the time period envisaged, including non-surge demands at the lower end of the spectrum. Those programs were provided by DoD agencies through NAVSEA in cooperation with MARAD. They are presented in full time-phased detail by ship types in Appendix A, which is classified, and are presented in compressed unclassified formats in Section B. The four scenarios are anchored on a base case that provides a slight build-up in terms of number of ships, and excursions are made to a lowest case that accepts some attrition in Navy size, an intermediate case that gives a substantial enhancement, and a highest case that more than doubles base case production. All four procurement cases are accompanied by the same MARAD-provided program for merchant and Coast Guard ships.

Sections C and D describe in detail the manner in which these scenarios are analyzed in order to derive estimates of the demands they place upon shipyard facilities, labor forces, and suppliers, as well as time needed to fulfill them. The results of these analyses will give insights into the implications of the impending shrinkage of the shipbuilding industry (see Chapter II), as well as insights into current capacity.

For each scenario, the methodology involved two steps: a formal analysis of the ship-to-yard allocation process within specified labor force constraints using a computer model, IDASAS,[1] and an informal review and modification of the IDASAS results to correct for its inevitable rigidities or inability

[1]IDA Ship Allocation System.

to incorporate some difficult-to-program considerations. The IDASAS structure, the criteria by which its allocations were made, and the various constraint sets that were used to simulate realistic labor force conditions are presented in detail. Finally, to finish the methodological presentation, the nature of the informal alterations or extensions of the IDASAS results is given.

The results of the analyses of the four programs are presented as responses to six questions:

(1) In the light of building position and labor force availabilities, how many Category I, II, and III, naval and other shipyards are indicated as sufficient to meet the FY 1995 force level target of each program?

(2) If the programs were stripped of their commercial ships, and only naval ships were considered, how many yards would be required to produce the military components?

(3) For a given set of shipyards derived from NAVSEA's[1] analysis of each program, how might reallocations of ships within this set of yards permit the time of build-up to be shortened?

(4) Again for a given set of shipyards derived from NAVSEA's analysis of each program, how much time could be saved by eliminating the commercial construction program (i.e., by building only naval ships in U.S. yards)?

(5) For the same sets of shipyards, how long would each program take if all *surface* nuclear ships were eliminated and their conventionally powered counterparts substituted?

(6) For the same set of shipyards, how long would each program take if commercial construction were eliminated, nuclear surface ships were replaced by conventional counterparts, and all labor constraints were relaxed?

The answers to questions (1) and (2) are reported in Section G and give policymakers some insights into the step-up in the size of procurement base implied by each program

[1]NAVSEA provided a feasibility analysis of its own for each program. See below for descriptions and results.

increment, to the extent that size is measured by the number of shipyards necessary for its provision. The analysis does not undertake a study of the economic costs in terms of resource absorption attendant upon keeping the indicated surge potential in existence.

The times-to-completion of the four programs are also variables to minimize; the answers to the third question (detailed in Section H) give some indications of the minimum time required to build the ships contained in each procurement case. Planning factors for construction times are peculiarly important in these derivations, and the study analyzes each procurement case for four different planning factor sets to test sensitivity. Although the results are tentative, some important indications of the time elasticities in the programs have been derived.

The answers to questions four through six, also presented in Section H, give some insight into the effectiveness of various policies which might be followed should a faster rate of Navy build-up be required.

B. THE FOUR PROCUREMENT CASES

The four detailed procurement cases, being classified, are isolated in Apppendix A of this report. In Tables 4-1 and 4-2 the study team aggregates the data in unclassified forms for the purpose of displaying force level impacts and levels of overall activity implied by each case. Table 4-1 indicates that in terms of total numbers and construction values of ships produced, as well as numbers of ships plus conversions, the relations of the other cases to the base case are reasonably stable. The lowest case reduces base case ship construction effort by about one-third, the intermediate case increases it by about two-thirds, and the highest case more than doubles base case activity.

Table 4-1. DIMENSIONS OF THE PROCUREMENT CASES

Case		Estimated Construction Costs[a] (1979 Dollars)	Ships Awarded FY82-FY91	Conversions FY82-FY91	Force Size[b] 1995	Ratios: Cost	Ratios: New Ships	Ratios: New Ships Plus Conversions
1. Military								
Base		$66 billion	197	20	581	1.00	1.00	1.00
Lowest		45	132	20	518	.68	.67	.70
Intermediate		107	330	23	700	1.63	1.68	1.63
Highest		137	437	20	821	2.08	2.22	2.11
2. Commercial								
Ocean	All Cases		144	6				
Great Lakes	All Cases		8	-				
Coast Guard	All Cases		57	-				

[a] Information from NAVSEA indicates that these cost estimates are probably low. They should be used for comparison only.

[b] Force Size 1981: 546. Includes MSC and some Reserve ships.

Table 4-2. PROCUREMENT CASES, TIME-PHASED BY YEAR OF CONTRACT AWARD, WITH FORCE SIZES

Case	Awards, Fiscal Years: New Construction (Conversions)											Force Sizes[a]	
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Totals	FY 1981	FY 1995
Navy:													
Base	17(3)	16(6)	20(6)	21(2)	24	19(1)	26	19	15(1)	20(1)	197(20)	546	581
Lowest	18(6)	15(6)	12(4)	17(1)	16	15(1)	9	9	10(1)	11(1)	132(20)	546	518
Intermediate	29(3)	34(8)	32(7)	32(2)	33	32(1)	35	35	34(2)	34	330(23)	546	700
Highest	14(1)	33(5)	44(7)	54(3)	56(1)	51(1)	51	57	44(1)	33(1)	437(20)	546	821
Commercial:													
All	24	18	21	20(3)	19(3)	15	11	14	10	0	152(6)	--	--
Coast Guard:													
All	4	2	3	3	4	8	9	8	8	8	57	--	--

Source: NAVSEA Memorandum reproduced in Appendix A.

[a]Force sizes include MSC and some Reserve ships.

The FY 1995 force level shown to result from each case was provided by NAVSEA. It is important to recognize that these targets are accurate only for those IDASAS runs which adhered to the award schedule provided with each case. This was done in all runs minimizing the number of yards used, but the award schedules were necessarily abandoned in those runs which minimized time. However, where IDASAS is able to build a program more quickly, one may assume that force levels will increase more rapidly.[1]

For comparison, the FY 1981 force level is about 546 ships. All of these quotations include Military Sealift Command (MSC) and some Reserve ships.

In each program, a few ships are scheduled for delivery after FY 1995. The number of these in each is shown on the tables giving results, along with the actual number which IDASAS was forced to deliver late.

Table 4-2 displays ship totals distributed over the period FY 1982-FY 1991 by the year their orders are placed with the yards. The base case, which is derived from the Navy Five Year Defense Plan (FYDP), projects a rather level loading of the yards through the period in numbers that are close to current Navy orders. Although force levels increase slightly, much of this is in MSC at the expense of slight attrition of large combatants.

The lowest case for the Navy projects a loading pattern which trends downward over the years, with a rather severe fall off in orders beginning in 1988. Designed as a projection of orders if funding does not keep pace with inflation, its new construction orders total to only 67 percent of those in the base case. FY 1995 force levels consequently are 11 percent

[1]The impact on force levels of these results could not be specified with precision, owing to a lack of sufficient information about current Navy force levels and retirement schedules.

less than those reached by the base case, with rather severe attrition of large surface combatants through retirements.

The intermediate case is a NAVSEA development. It is designed to build a number and mixture of ships that will eventually permit a jump to the highest case force level in only five years. This is accomplished in three ways: first, the force level is increased to 700 ships, 35 percent above the base case target, meaning that fewer ships would have to be built in a hurry; second, Ingalls is assumed to become nuclear qualified, both to handle the large number of nuclear ships built in the intermediate case and to help alleviate the industry's shortage of nuclear capability; third, awards are made so that yards are level-loaded, increasing their financial health and productivity.

Accomplishing these goals requires that two-thirds more ships be built than are in the base case, resulting in typical annual orders of 32 to 34 ships.

Finally, the naval loading pattern of the highest case reveals an average of 44 ships built per year, with a three-year front load build-up to a 50+ pattern of orders in the 1980's and a two-year winding down in the early 1990's. Historically, in only one year in the post war period have new Navy orders been as high as 50--in 1966, the peak of the Vietnam build-up, when they reached 54. The highest case provides, therefore, a sustained and almost unprecedented peacetime workload for relevant yards, with orders 121 percent above base case orders, and a final force size which at 821 ships is 41 percent above the base case value. When MSC and Reserve Units are subtracted, this is the 770-ship Navy, a more commonly recognized number.

The commercial-Coast Guard programming, an estimate provided by MARAD, is combined with each of the naval programs to simulate total workloads for the industry. It projects a steady annual loading of 20 to 23 ships from 1983 through 1989, with

some heavy front loading in 1982 and a tailoff in 1990 and 1991. These orders are representative of recent levels.

In short, the four programs afford the opportunity of studying the stresses placed upon the shipbuilding industry over a 10-15 year period of attaining a 500, 600, 700, and 800 ship Navy, with average annual new construction orders of 13, 20, 33, and 44 ships. To complete the overall industry loading estimate, an average of 21 nonmilitary ships are added in each year.

It must be noted that the descriptions of the purpose of each case apply in full only to the results of the NAVSEA analysis of each. Their intent was often to provide realistic projections of award patterns under current conditions, while this study will use IDASAS to produce estimates of industry capacity in surge situations. However, as noted above, since the FY 1995 force level targets provided by NAVSEA are linked to their award schedule for each case, their *time-phasing* of orders will be accepted in the analyses of the programs' facilities-labor feasibility. Of course, the actual pattern of usage of the yards is likely to be different.

In the analysis of time conservation, the study will alter these patterns to try and achieve the greater build-up rates likely in a surge, thus shortening time-to-completion of the programs.

C. METHODOLOGY FOR THE FEASIBILITY ANALYSES

Constant Maximum Program vs Variable Maximum Program

In approaching this analysis it was necessary to make a crucial decision with important implications in terms of interpreting this task and in determining the solutions sought. The choice springs from the conclusion that some explicit maximum program has to be envisaged in policy making whose purpose is to fix upon the size of a shipbuilding procurement base that

should be preserved. Once that maximum program benchmark is accepted, it becomes a highest case and analyses of nonsurge demand cases must proceed within guidelines determined by the need to preserve it.

Suppose policymakers decided to protect a maritime acquisition base implied by the highest program of this study, or a capability to build up to an 821-ship Navy plus 200 nonmilitary ship fleet additions or replacements in a 14 year period. Then, those policymakers would approach the analysis of the intermediate, base, or lowest cases with questions of the form: If it is decided to build at the present time a program of less than maximum case size, what allocations of ships *to the whole set of yards necessary for the highest program* should be anticipated? That is, what pattern of awards would provide at least minimum workload support for these maximal-case yards (ignoring what subsidy or other programs might be necessary)?

The important element in such an analysis is that the highest case must be solved first to determine the set of yards necessary to produce it, and that set of yards drives the analyses of any lesser procurement cases. That is, the maximum case is kept *constant* and fixed, and the other cases are analyzed within the bounds it determines. This is termed the *constant maximum program* (CMP) approach to the analysis of procurement cases.

A CMP approach becomes relevant when it can be assumed that a highest or maximum procurement program has been adopted. However, suppose the purpose of the analysis is to aid in the choice of the highest case, or to see what size procurement base *would be* necessary *if* a given force size were planned? If, for example, the intermediate case, with its 700-ship Navy, were made a highest case, what number of yards would be necessary to produce it? What increment in number of yards does that imply

over the base case? In each case, the procurement programs and the number of yards is free to vary rather than being held fixed. Therefore, this second methodology is termed the *variable maximum program* (VMP) approach.

The IDA task has been interpreted as implying the desirability of a primarily VMP approach. First, no guidelines were given that led to the belief that any of the four programs analyzed or some program that approximated any of them had been determined to be the maximum program. Hence, it seemed logical to assume that each case should be analyzed on its own ground. Second, it seemed reasonable that DoD and Congressional planners would be more interested in assessing procurement base sizes implied by various force size alternatives than in the narrower question of the manner in which ships would have to be distributed over some postulated maximal program yard set to preserve it.

D. THE IDASAS PROGRAM

1. Introduction

The IDA Ship Allocation System (IDASAS) was developed to allocate ship awards hypothetically to specific shipyards under a spectrum of constraints. It is a computerized simulation model capable of providing answers to a variety of questions rapidly and objectively.

Any means of deriving notional allocations of ships into yards must take account of the three major constraints on shipbuilding industry output: facilities, labor, and materials; IDASAS is no exception. However, additional requirements were imposed by the nature of the analyses to be performed. First, the desire to minimize the time or number of yards needed for each case implied that each yard should be used to the limit of its facilities or labor capacity. Second, obtaining the benefits of extensive sensitivity analysis required that the simulation be as completely computerized as possible. The

following sections will describe how these goals have been effected.

2. IDASAS's Input Structure

IDASAS requires the following information as inputs:

(1) Number of ships to be built

(2) Number of yards available

(3) For each ship:

- (a) Type
- (b) Size
- (c) Planning factors for building time
- (d) Labor requirements
- (e) Complexity index:

  Combatant
  Auxiliary/amphibious
  Nonmilitary

- (f) Qualified yards (if more than complexity index must be considered)
- (g) Year of award (NAVSEA determined)

(4) For each yard:

- (a) Name
- (b) Number of building positions available for new construction
- (c) Size of each position
- (d) Date position is free of current construction
- (e) Qualification level of yard
- (f) Employment ceiling for yard
- (g) Maximum labor force expansion rate for yard
- (h) Minimum subsistence employment level
- (i) New construction employment necessary through 1985, by quarters, to complete current work in progress and ships on order (quarterly)
- (j) Employment (quarterly) necessary to complete estimated average repair load in yards involved in repair work.

3. IDASAS Execution

In the five runs for each procurement case defined by input parameters and for which the number of yards used is *minimized*, Figure 4-1 charts the flow of program execution. The program

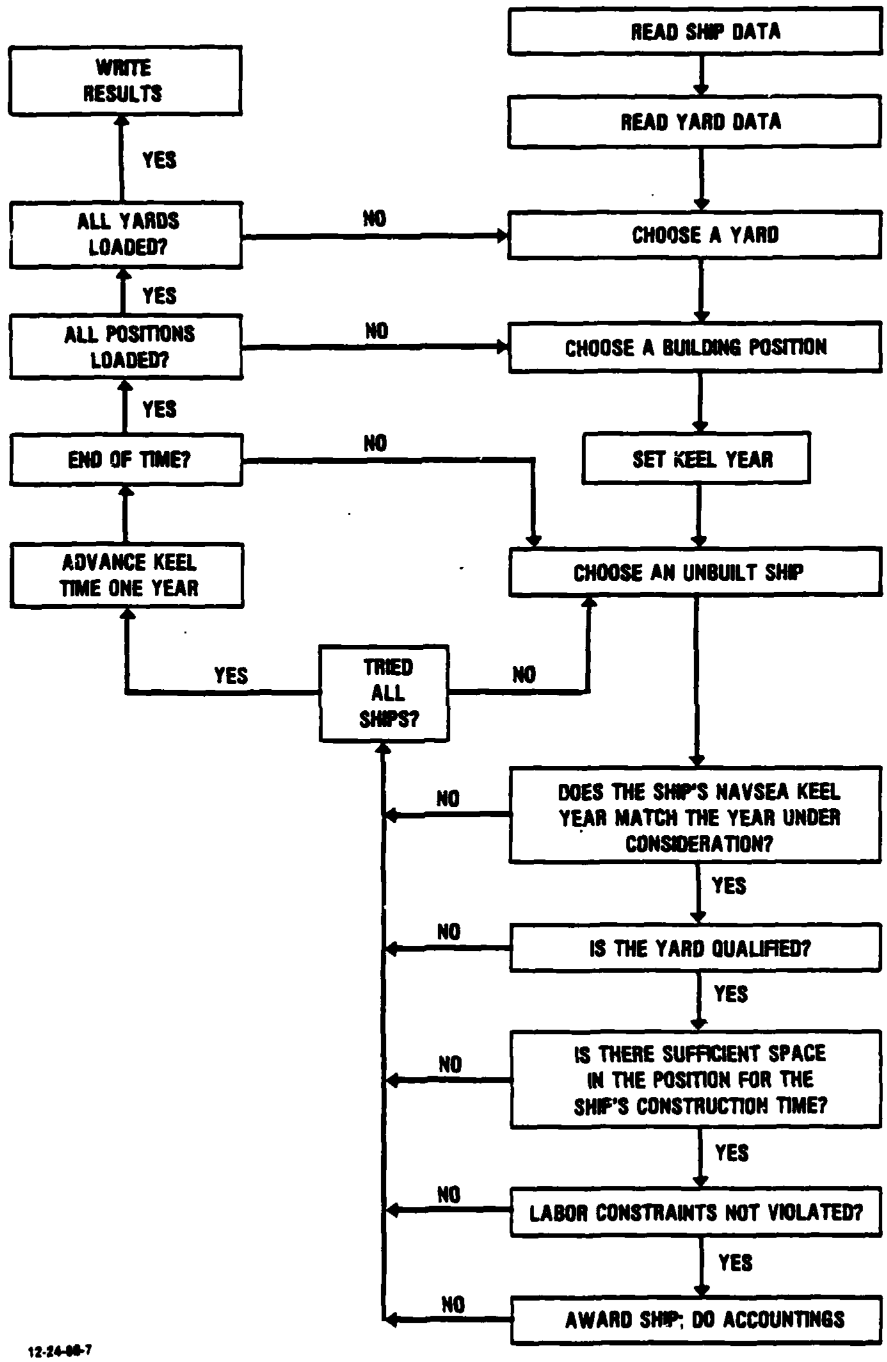

Figure 4-1. IDASAS CONCEPTUAL FLOWCHART: YARDS-MINIMIZATION VERSION

selects yards in descending order of size, filling each to capacity over the entire period specified (14 years in our analyses) before moving to the next yard listed.

Each building position in a yard is filled over the period before the next is considered. It is also possible to predetermine awards of ships to positions if the desire to override the program's allocation routine exists.

Ships whose keels are to be laid in the relevant year are assigned to positions in yards which are qualified. For each such ship, the building position is checked to see if it can accommodate the ship from keel laying to launch, and, if more than one ship is being built in it simultaneously, whether it can afford the ship a clear way to water on its launch date. If both tests are passed, the ship's impact on the yard's employment pattern is checked for possible breaches of its labor ceilings. If again successful, the ship is assigned to the position and necessary bookkeeping is accomplished. The program then moves once more to the top of the ship list.

If all ships are so considered and fail of selection, the program increments to the next keel year, moving through the years for the building position under consideration, and filling it to capacity over the period. Figure 4-2 gives a visual depiction of this assignment process. Length of building position is graphed on the x-axis and time in months on the other. Each block depicts the amount of space a ship will occupy in the building position (length) and the block of time during which it will be positioned (depth).

The allocation stops when (1) all ships have been built, or (2) the last position in the last yard has been run through.

In one simulation run for each procurement program, it was desired to *maximize* the number of yards operating at minimum viable employment levels. This, in combination with the other results, will help give some impression of the impact on the

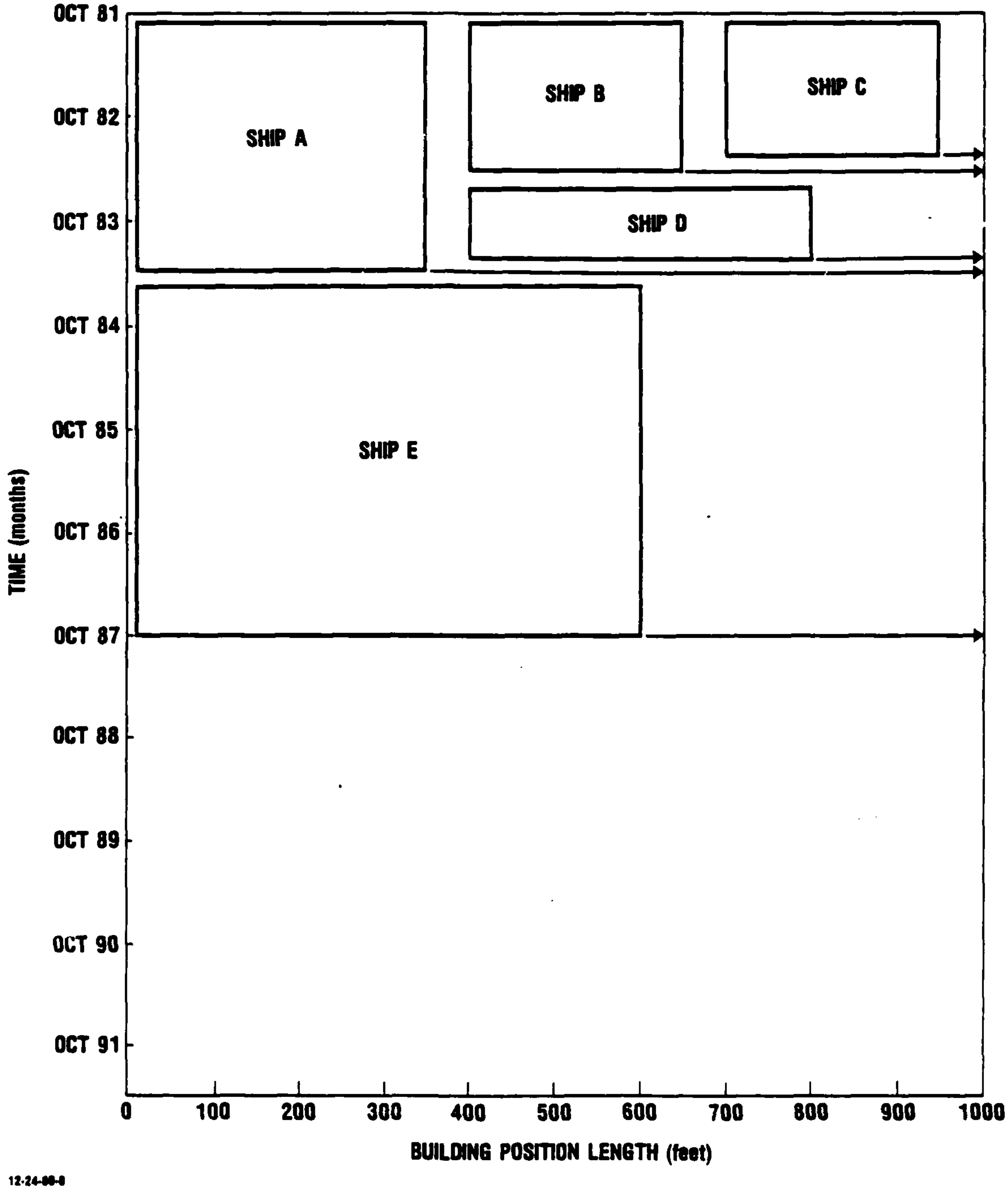

Figure 4-2. THE ALLOCATION OF SHIPS TO A BUILDING POSITION

industry of each of the programs. However, it is only one of the avenues which a primarily CMP approach might follow. As noted, we have chosen to concentrate on a VMP approach.

A variation of the execution logic is required in this version as indicated by its flow-chart in Figure 4-3. In an initiating cycle for each building position, a set of priority ships (nuclear ships and conventional carriers) is scanned and awards made where possible. In following iterations, when nonpriority ships are assigned, the recipient yard's employment level is checked for one year from the year of projected keel-laying. If the yard's minimum employment level is exceeded, the keel-consideration year is incremented by one year. The program then executes in a manner similar to that for yard-minimization.

Finally, IDASAS has been used to *minimize the time of total program construction.* Its major change in execution mode from the previous two is that the order of execution alters to fill *all* empty building positions with keels year by year, subject to labor constraints. Each building position is considered in sequence and its qualifications are examined as in earlier versions. However, a ship's keel may be laid whenever the program chooses, instead of following the award schedule provided by NAVSEA. Hence, the program moves from building position to position in a given year rather than from year to year for a given position. The flow-chart is given in Figure 4-4.

It should be noted that in all IDASAS versions facilities and labor are reserved for commercial repair work in private yards doing such work. When Naval yards are used for new construction, facilities are reserved for repair, but the repair capacity of these yards may be diminished.

4. Some Limitations and Caveats

The reader may have noticed that after defining "materials" as one of the three basic constraints on shipbuilding industry

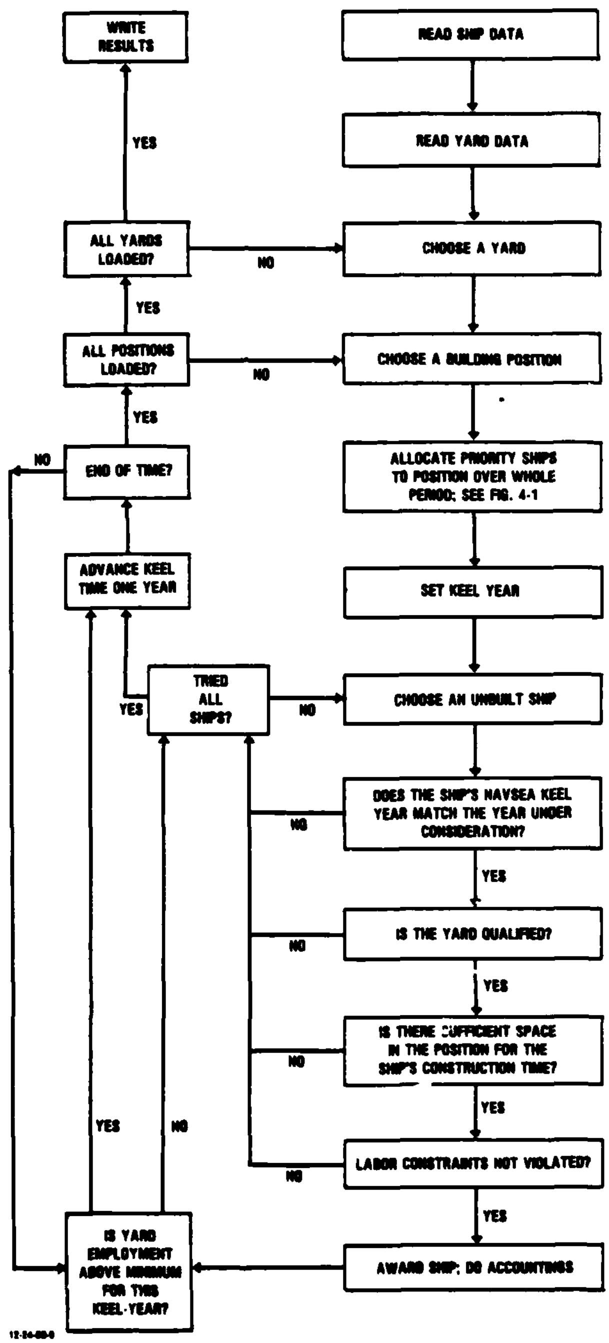

Figure 4-3. IDASAS CONCEPTUAL FLOWCHART: YARDS-MAXIMIZATION VERSION

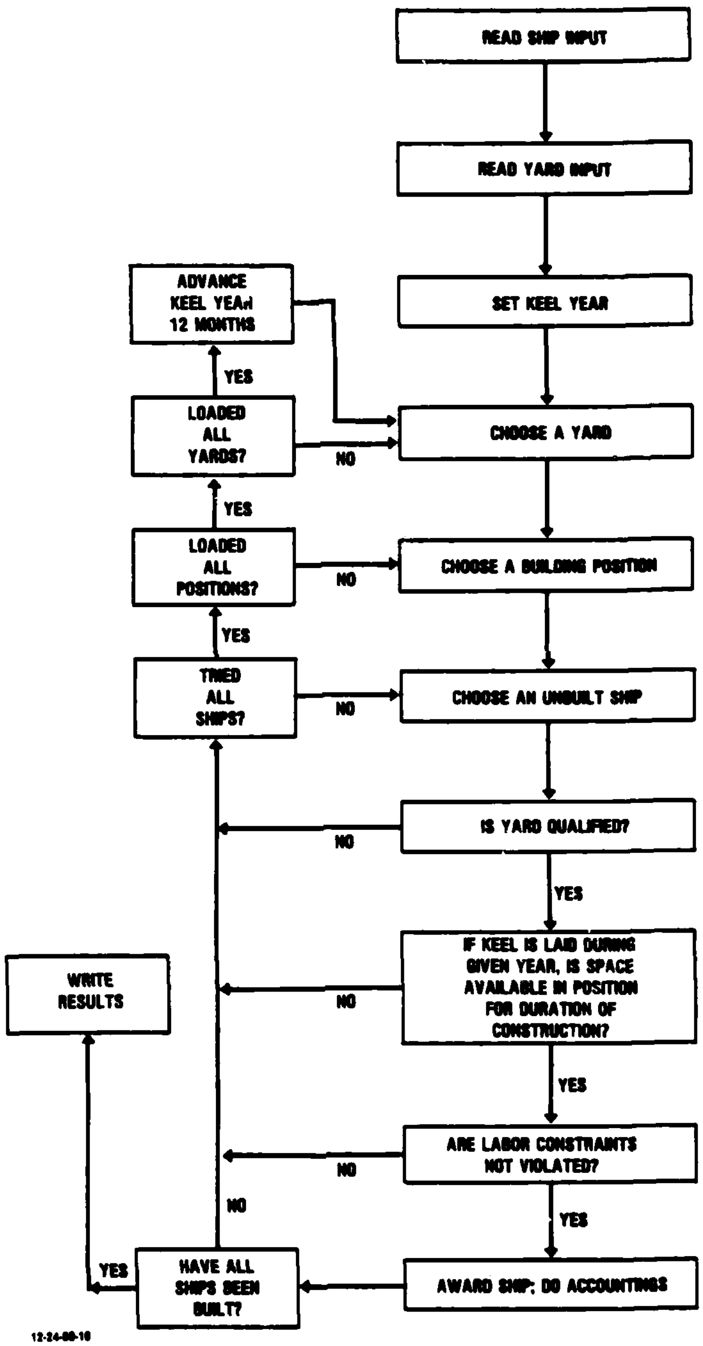

Figure 4-4. IDASAS CONCEPTUAL FLOWCHART: TIME MINIMIZATION VERSION

output, we proceeded to describe a model which nowhere takes account of materials and component availability.

This is a chronic problem for those simulating the industry, since a thorough treatment would involve a reasonably complete submodel of supporting industries, including estimates and effects of demand by other sectors of the economy. Such a model does not exist, nor were time and personnel resources for this project great enough to permit development of one.

NAVSEA's approach to this problem is to request the Navy Shipbuilding Scheduling Office (NAVSHIPSO), which keeps track of lead times for a few hundred materials and components, to examine its assignments and detail any expected problems. This was done for their assignment of the highest case used here, with only two under-development radars and weapons systems pinpointed as bottlenecks.

We feel that this may be somewhat optimistic, given the conclusions this study reached in Chapter III; it is almost certain that supplier problems would result if the times-to-completion of the cases were shortened, as they are in many IDASAS runs.

However, it appears that defense priorities could be invoked if conditions were such that a major surge in shipbuilding were required, and that the long building periods of ships would allow sufficient time for government owned and/or operated expansions of facilities if such were necessary.

Some discussion of the method of dealing with yard qualifications is required; the study depended upon NAVSEA judgments at this juncture. Although some ships can be built only in specific yards (e.g., SSBN's in Electric Boat or CVN's in Newport News), in general yards were divided into four classes:

- nuclear-capable
- combatant-capable

- auxiliary-amphibious capable
- non-military only.

Nuclear capability was easy to assess. Electric Boat and Newport News are nuclear qualified for all procurement cases, Ingalls is so qualified for the intermediate case, and naval shipyards are deemed qualified in all cases. Other yards were divided among the remaining three classes according to the most complex ship NAVSEA awarded them in its analyses.

This method does not measure capability in dimensions other than building-position appropriateness. An implicit assumption is that such positions will have the shops, equipment, and personnel necessary to support the level of complexity assigned them.

No attention has been given to the possibility that limits on management abilities in the yards exist. It has been suggested[1] that yard managements find it difficult to produce a few each of a large number of ship types, but can efficiently produce large numbers of a few ship types. Making assignments so that yards specialize in production of only a few types can lead to underutilization of capacity; in a study examining the limits of industry capacity it was deemed undesirable to introduce this upward bias without more proof of the validity of the assertion. However, to the extent that yards are unable to build a variety of ships on schedule, more yards and/or more time will be necessary than IDASAS indicates.

The approximate nature of the results is emphasized for each of the procurement cases. In this, no doubt, this analysis shares the deficiencies of other methods, and perhaps escapes a few to which they are heir. Data inputs are imprecise, notably the building times necessary in ship construction. The study sought to escape some of these deficiencies by extensive

[1]Discussions with NAVSEA personnel.

sensitivity analysis, bracketing the parameters with lowest and highest cases.

None of the versions of IDASAS is guaranteed to produce "best" solutions. Rather, it is designed to yield "very good" solutions which probably could be improved upon by successive iterations in a truly optimizing simulation. That type of simulation was beyond time and personnel constraints for this project. IDASAS does provide an efficient usage of industry facilities rapidly and objectively.

With this in mind, it is important to remember that IDASAS results reflect assumptions of "hitchless" time-phasing and construction processes. As a complex component-gathering, sequence-dominated, specification changing operation, shipbuilding, as seen in Chapter II, is prone to experience errors, delays, and changes. Therefore, *IDASAS results should be interpreted as biased toward minimum numbers of yards or amounts of time needed to produce procurement programs under the specified constraints*. No doubt, realistic expectations demand that some slack be allowed in the system to accommodate the inevitable frictions.

It follows that for runs in which no constraints other than facilities availability are included, or where less than a full set of labor constraints is active, IDASAS results are even better than the already unrealistically good results achieved with "full" sets of constraints. Such results may, therefore, be below reasonable lower-limit estimates of yards or time required for the given programs, at least under current peacetime conditions.

On the other hand, when, in conditions of surge demand, IDASAS finds it impossible to place all ships within building positions, it follows that rather solid indication of an infeasible program is given.

In short, it must be kept in mind that both IDASAS and other methods are blunt instruments, not tools of surgical precision. They can at best give insights in order-of-magnitude terms into a realistic shipbuilding problem whose complexity inspires humility.

E. CRITERIA AND CONSTRAINTS FOR PROGRAM FEASIBILITY ANALYSIS

For each of the four procurement cases, six IDASAS runs were made, subjecting the allocations of ships to yards to different labor constraints in each run, in order to analyze the feasibility of the programs with given shipyard capacities, and to estimate how far the shipbuilding base might shrink before a given program becomes infeasible. The purpose of performing the analyses with multiple parameter sets was to study the sensitivity of the solutions to a variety of potential limitations that might be encountered in periods of surge demand. *The robustness of* IDASAS's solutions under different environments was an important consideration in interpreting the plausibility of the results. Moreover, the variability of the solutions provided brackets within which the size of the required procurement base could be expected to vary under unforeseeable conditions, and hence the multiple solutions provide the policymaker a means of coping in his planning with some types of uncertainty.

The six constraint sets are listed below, and their nature is indicated.

Constraint Set 1. In this run no constraints with respect to labor were imposed on the solution. The purpose of this solution is to obtain the absolute minimum number of yards that could build each of the four procurement case programs. Only building positions in the yards are potentially constraining. Special labor incentives would probably be needed.

Constraint Set 2. NAVSEA has determined for each yard in the relevant set a maximum mobilization labor force employable

with existing facilities. These values are listed in Table 2-3. This set of relevant yards has been complemented by two other sets of yards: a group of 12 "supplementary" firms, many of which are now engaged only in repair work but which have construction capability, and the four naval shipyards that still possess the capacity for new construction. The composition of these sets are specified exactly below. The analysis does not constrain either of these groups of yards by maximum employment limits.

Constraint Set 3. To the maximum labor force constraints of Set 2, assumed labor expansion rate maxima for the 25 relevant shipyards are added. After studying the historical labor rate expansion analysis of Chapter III, it was decided that an expansion rate of 25 percent per year was, with certain exceptions, a most likely maximum for relevant yards. This restraint was relaxed under four conditions:

(1) The supplementary and naval shipyard sets were exempted from rate-of-expansion constraints, since no labor force maxima were specified for them.

(2) If a relevant yard's employment is less than 750. In such cases the absolute numbers involved in expanding are small enough not to be troublesome.

(3) If a yard's employment level at any time in the simulation is below that of the first quarter of FY 1982, it is permitted to increase at a rate up to 100 percent per year until it reaches that level. At that point, the rate constraint binds. This exclusion is designed to permit the yards to lay off employees during temporary lulls in activity without losing them completely when workloads increase.

(4) Any yard is permitted to increase labor force up to 100 percent per year through FY 1985. This reflects our judgment of labor force slack in the system at present.

The inclusion of a maximum rate of annual increase in labor force as well as a maximum level of employment provides a manner of simulating the imperfect regional mobility of shipyard labor and the potential need to recruit it from other industries or

to train it.[1] It would have been preferable to custom this rate constraint to each relevant yard, or perhaps to each region, but this would have complicated an already complex model to a degree unjustified by the gains in precision.

The solutions from IDASAS for this set of parameters are treated as those for the "most likely case;" however, that phrase should be interpreted in the light of the ideal minimum nature of all IDASAS results.

Constraint Set 4. This set of parameters is identical to that of Set 3 except that the maximum labor rate of expansion constraint was set at three-fourths of the assumed rate of 25 percent, or at 19 percent per year. All of the exceptions listed in the discussion of Set 3 are in effect. This permits testing the sensitivity of our solutions to the possibility of a tighter labor market than projected in Constraint Set 3.

Constraint Set 5. Once more the parameter set of Constraint Set 3 is repeated except that the 25 percent labor expansion rate ceiling is raised by a factor of 1.5, or to a level of 38 percent. All exclusions remain in effect. These runs permit the gauging of the robustness of the solutions to a labor market that remains through the period of analysis a relatively loose one.

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[1] When labor usage is considered in studies of the shipbuilding industry, questions about the number of shifts employed in yards often arise. Often, an unspoken assumption is that yards work on a one-shift basis when demand is not high. In fact, many yards operate three shifts regardless of the level of demand, although the majority of employees work the first shift. A typical pattern is 60 percent of employees on the first shift, 30 percent on the second and 10 percent on the third. IDASAS keeps track of labor on a total-yard basis, without dividing it into shifts, and all employees work a 40-hour week. The labor requirements for each ship under construction in a given yard are simply summed for comparison with constraints. An implicit assumption, however, is that yards will tend to assign higher percentages of employees to the second and third shifts as the total number of employees increases.

Constraint Set 6. Finally, in this set of runs, the study asked the question "If the ships were spread among relevant yards in a manner that just preserves the viability of each yard, how many yards could be sustained by each of the four programs?" In the other five simulation runs the desire was to minimize the number of yards employed subject to the constraint sets. This last run goes to the other extreme to award ships up to a minimum labor force level which just keeps each yard in business and hence maximizes the size of the procurement base. The minimum labor forces for the shipyards were estimated on the basis of historical data for the 1970's. It should be noted that nuclear ships and carriers were awarded to qualified yards without reference to these minimum levels, as indicated in Section D.

The results produced by Constraint Set 6 will be especially useful for the lowest and base cases, which are not far from current Navy procurement levels. This brief excursion into CMP analysis will help to test the assertion, made in Chapter II, that continuation of current trends implies attrition of yards from the industry.

These constraint sets' contents are summarized in Table 4-3. For each procurement case--base, lowest, intermediate, and highest--an IDASAS run using each of the above constraint sets was made. In the five minimizing runs, the study worked under an hypothesis that has not been proved: that the real economic costs to the nation of keeping more shipbuilding capacity in existence than is necessary to prepare for the maximum case are not negligible. It has been urged in Chapter II that studies of the real cost of preserving units of an uneconomic industry be launched. Absent that analysis we assume that it is most economical to minimize shipyard capacity; this is one motivation of the desire to minimize yards.

Table 4-3. CONTENTS OF THE SIX CONSTRAINT SETS FOR THE FEASIBILITY ANALYSES

Constraint Set	Building Positions	Maximum Labor Force Level	25% Annual Maximum Labor Force Expansion Rate[a]	19% Annual Maximum Labor Force Expansion Rate[a]	38% Annual Maximum Labor Force Expansion Rate[a]	Maximize Number of Yards
1	*	-	-	-	-	-
2	*	*	-	-	-	-
3	*	*	*	-	-	-
4	*	*	-	*	-	-
5	*	*	-	-	*	-
6	*	-	-	-	-	*

[a]With exceptions noted in text.

It is realized that when this type of policy was followed in the past under total package procurement--as discussed in Section B of Chapter II--some yards were saturated with orders, which led to problems of overly rapid expansion of labor force and management responsibilities. The labor force constraints will help to protect against this saturation, but of course potential management inefficiencies could not be anticipated. Therefore, the formal minimization of yards employed cannot be taken as a final recommendation of the wisdom of performing the procurement in this manner, for costs have nowhere been taken into account explicitly in the analysis. It might be shown that the economic costs of keeping yards in existence is cheaper than the costs of diseconomies that occur when fewer yards are congested.

Still another consideration argues that the procurement programs would not be built with the minimum number of yards. As was shown in Chapter II, shipyards are under tremendous pressure to seek work at prices very little above variable costs in periods of slack in order to cover fixed costs and to hold

their core labor force together. Therefore, if competitive negotiation is used for contract awards, it must be expected that idle yards would submit lower bids than yards already busy and thus would build ships even though their capacity was "unneeded" in the IDASAS runs.

Despite these considerations it was felt that minimizing the number of shipyards in a Variable Maximum Program (VMP) approach to each of the four procurement programs is most valuable for the purposes of this study. Such analyses permit policymakers insights into the problem of maintaining a core of capacity that *can* produce a given program if the need arises. That capacity provides a floor below which it would be dangerous to permit the industry to fall. Capacity above this amount might be more or less economic, in the sense of program costs and the need for slack to accommodate realistic frictions, and might be more conformant to free market practice. Those considerations are important, but they are somewhat less pressing than the national security need to provide the core of a supply base.

In order to simulate policy decisions that might be made in periods of extreme naval demand pressures upon shipyards, the study incorporates for each procurement case an IDASAS analysis of the naval ship program only, omitting the Coast Guard and merchant ships on the assumption that national policy would dictate having these produced in foreign yards. This reduced program was solved in each case for all six parameter sets. Those solutions give some indication of the relief obtainable in surge demand periods by employment of this rather drastic policy measure.

Informal Analysis

IDASAS results were employed as an initial aid in the analysis, allocating ships in the manner explained in Section D.

Because the model may be unable to find labor or unused building positions or because of the rigid and noniterative nature of its logic, an IDASAS run will occasionally terminate without assigning all ships. The pattern of assignments was then studied to discern the cause, and where the logic was incomplete ship assignments were reallocated among yards to accommodate the unassigned ships. These in all cases were a small fraction of the ships built.

F. METHODOLOGY OF THE ANALYSIS OF TIME CONSERVATION

Criteria and Constraints

A second question addressed concerned the time necessary to build the four programs. In all of the above analyses 10 years were required to accomplish the awards of ship contracts, and the last ships were finished in either 15 years (lowest and intermediate cases) or 16 years (base and highest cases). Of course, for those programs for which IDASAS did not require usage of all shipyard capacity it is possible to include more yards than the program finds necessary and thereby reduce time to completion, always providing such actions do not require unattainable reductions in the lead times of potentially tight components such as weapons systems. However, since any number of analyses could be run depending upon the number of yards one was willing to support, and because no cost analysis was available to indicate the tradeoff between time reduction and increased cost, no economic basis existed for choosing an acceptable number of yards.

For this study, NAVSEA's solution with respect to the number and identity of shipyards needed to build each case was accepted so that some comparability with their results would be maintained. The ships were then reallocated among yards and in different temporal patterns to see if time savings could be achieved.

In order to study the sensitivity of the minimum-time allocations to assumed times necessary for construction of each type of ship, four runs were made for each of the programs. The parameters consist of planning factors (discussed in Chapters II and III) for time required for successive stages in ship construction. Each run was made with Constraint Set 3 (facilities, employment ceilings, and 25 percent per year employment expansion rate limit), described more fully above, in effect.[1] The sets are the following:

Factor Set 1. In the first set current NAVSEA planning factors were used for the time necessary from contract award to the start of construction, from start of construction to keel-laying, from keel-laying to launch and from launch to delivery.

Factor Set 2. In this set the planning factors for naval ships were reduced by multiplying NAVSEA factors by 0.8. Merchant and Coast Guard factors were left unchanged. This set of runs permits study of times-to-completion of the programs in response to ship standardization or other measures which might be aimed at speeding up the building process.

Factor Set 3. The planning factors of Factor Set 1 were multiplied by 1.2 to provide a check against the overoptimism that may characterize the use of normal planning factors for periods of surge demand. Once again, commercial ship factors were left unchanged from their Factor Set 1 levels.

Factor Set 4. Recent delivery times for certain types of naval ships were obtained[2] and these historical averages were substituted for the NAVSEA-estimated factors of Factor Set 1. Where historical data could not be obtained, the Factor Set 1 data were retained. It was possible to substitute for the following ship types: CVN, CGN, SSN-688, DD, FFG, LSD, LHDX, LPDX,

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[1]Exclusion 4, as detailed on page 4-23, was not in effect for these runs.

[2]Obtained from NAVSEA.

AS, AE, and AOR. It was felt that in a few cases such factors might update NAVSEA data, and would help to correct such biases toward optimism or pessimism as might exist in the Factor Set 1 values.

The contents of the planning factor sets are summarized in Table 4-4 for ready reference.

Table 4-4. CONTENTS OF THE FOUR PLANNING FACTOR SETS FOR THE TIME CONSERVATION ANALYSES (CONSTRAINT SET 3 IN EFFECT FOR ALL)

Planning Factor Set	NAVSEA	NAVSEA x .8	NAVSEA x 1.2	Historical
1	*	-	-	-
2	-	*	-	-
3	-	-	*	-
4	-	-	-	*

IDASAS was used to find the minimum number of years necessary to produce each program under the relevant planning factor set, subject to yard choices dictated by NAVSEA's solution for that particular program. For each set of factors and for each program two measures of time required were determined. The first period was the number of years that was required before the last ship was delivered. Since this last ship was in all cases a nuclear ship, the time to completion of the last conventional ship was also thought to be of interest.

Several options which might conceivably hasten construction of the programs were explored. The minimum time required to construct only the naval ship programs in the given yards was determined for each planning factor set, on the assumption that commercial ships could be built in foreign yards.

Since the results make it apparent that the nuclear ships in each program drive the time results, a better estimate of

the additional time they require than is obtainable from "time to completion of the last conventional ship" was considered desirable. The difficulty with those results is that they may not give a realistic idea of the period required to achieve *balanced* force additions, since they simply ignore the nuclear ships. Therefore, similar conventionally powered ships were substituted for all nuclear *surface* ships in each program (no substitution was possible in the case of submarines). Runs for this scenario were made using Factor Set 1 only.

Finally, tentative insights into program times under mobilization were obtained by minimizing the time required for each case under the assumption that there would be no commercial construction and no labor constraints. One run added the assumption that similar conventionally powered surface ships would be substituted for nuclear surface ships.

Before proceeding to the results, the reader may wish to inspect Figure 4-5a and 4-5b. These show, for both the feasibility (number of yards) and time analyses, the scenarios examined for each case. The "exploded" boxes in the lower portions of the figures detail the constraint variations used on each scenario-case combination. The figures form a condensed but complete "map" which may be referred to.

G. RESULTS OF THE FEASIBILITY ANALYSES

1. Base Case Procurement Program

In Table 4-5 the IDASAS results for the analysis of the facilities-labor feasibility of the base case program are presented. As noted, the program in its entirety, detailed by ship types and NAVSEA's assumed distribution of orders by years, being classified, may be found in Appendix A of this study.

Five categories of shipyards are distinguished in Table 4-5. Categories I, II, and III are the relevant shipyards of

		SCENARIOS	
CASE	RESULTING NAVY FORCE LEVEL (FY1995)	BUILD BOTH NAVAL SHIPS FROM CASE AND COMMERCIAL SHIP PROGRAM USING NAVSEA/MARAD AWARD SCHEDULE AND BUILDING TIMES ✓	BUILD NAVAL SHIPS ONLY USING NAVSEA AWARD SCHEDULE AND BUILDING TIMES ✓, †
BASE	581		
LOWEST	518		
INTERMEDIATE	700		
HIGHEST	821		

CONSTRAINT VARIATIONS FOR EACH OF THE ABOVE SCENARIOS

(A yard always must be qualified to build a given ship)

(1) MINIMIZE THE NUMBER OF YARDS; BUILDING POSITIONS ONLY

(2) MINIMIZE THE NUMBER OF YARDS; POSITIONS AND YARD EMPLOYMENT CEILINGS

*(3) MINIMIZE THE NUMBER OF YARDS; POSITIONS, CEILINGS, 25 PERCENT PER YEAR LABOR FORCE EXPANSION LIMIT

*(4) MINIMIZE THE NUMBER OF YARDS; POSITIONS, CEILINGS, 19 PERCENT PER YEAR LABOR FORCE EXPANSION LIMIT

*(5) MINIMIZE THE NUMBER OF YARDS; POSITIONS, CEILINGS, 38 PERCENT PER YEAR LABOR FORCE EXPANSION LIMIT

(6) MAXIMIZE THE NUMBER OF YARDS TO BE SUPPORTED BY SPECIFYING A MINIMUM VIABLE LABOR FORCE LEVEL FOR EACH, AND ALLOCATING ACCORDINGLY; KEEP FACILITIES AND 25 PERCENT PER YEAR LABOR EXPANSION CONSTRAINTS

✓ Implies quoted 1995 force levels.

† Commercial ships assumed to be built outside the U.S.

* Under certain circumstances, expansion rate constraints may be relaxed; see pp 4-23/24.

Figure 4-5a. RESEARCH DESIGN FOR NUMBER-OF-YARDS ANALYSIS (FEASIBILITY)

		SCENARIOS				
CASE	NUMBER OF SHIPS BUILT †	BUILD BOTH NAVAL SHIPS FROM CASE AND COMMERCIAL PROGRAM USING CONSTRAINT SET 3*	BUILD NAVAL SHIPS ONLY, USING CONSTRAINT SET 3*	BUILD BOTH NAVAL SHIPS FROM CASE AND COMMERCIAL PROGRAM, SUBSTITUTING CONVENTIONAL FOR NUCLEAR SURFACE SHIPS. USE CONSTRAINT SET 3*	BUILD NAVAL SHIPS ONLY, WITH NO LABOR CONSTRAINTS	BUILD NAVAL SHIPS ONLY WITH NO LABOR CONSTRAINTS, SUBSTITUTE CONVENTIONAL FOR NUCLEAR SURFACE SHIPS
BASE	217					
LOWEST	152					
INTERMEDIATE	353					
HIGHEST	457					

PLANNING FACTOR VARIATIONS

(1) NAVSEA-ESTIMATED SHIP BUILDING TIMES
(2) NAVSEA ESTIMATES, LESS 20 PERCENT
(3) NAVSEA ESTIMATES, PLUS 20 PERCENT
(4) NAVSEA ESTIMATES WITH SELECTED RECENT HISTORICAL AVERAGE TIMES

PLANNING FACTOR VARIATION

(1) NAVSEA-ESTIMATED SHIP BUILDING TIMES

† Where built, commercial ship program was 215 ships.

* Building positions, yard employment ceilings, and 25 percent per year yard labor force expansion limit (see exceptions 1, 2, 3 on pp 4-24.)

Figure 4-5b. RESEARCH DESIGN FOR TIME-MINIMIZATION ANALYSIS

Table 4.5. BASE CASE: SHIPYARDS UNDER SIX CONSTRAINT SETS (FY 1955 Force Level: 581)

Shipyard Categories	Constraint Set 1: No Labor Constraint	2: Maximum Labor Force	3: Maximum Labor Force, 25 Percent Expansion	4: Maximum Labor Force, 19 Percent Expansion	5: Maximum Labor Force, 38 Percent Expansion	6: Maximum Yards
I	6	6	8	7	8	9
II	1	1	2	2	1	4
III	2	2	2	2	2	2
S	1	1	2	3	2	3
Total Private	10	10	14	14	13	18
Naval	0	0	0	0	0	0
Total Yards	10	10	14	14	13	18
Ships Delivered by 1995[a]	431	430	430	430	430	428
Ships Delivered after 1995[b]	1	2	2	2	2	4
Total Ships[a]	432	432	432	432	432	432

[a]Includes conversions.
[b]Number of ships scheduled for delivery after 1995: 1.

Chapter II, as listed in Table 2-3. It shows most of the yards judged capable of producing ocean-going ships under normal conditions. The Category S (Supplementary) yards form a group of 12 shipyards which are normally engaged only in repair or in commercial construction, but which NAVSEA has judged would also have a limited capability to produce commercial or even naval ships in periods of facilities stress. The last category includes the four naval shipyards that still posse ..ipbuilding capacity. These two new categories are identified in Table 4-6.

Table 4-6. DEFINITION OF ADDITIONAL SHIPYARD CATEGORIES

1. CATEGORY S:	2. NAVAL:
American Marine Corp., New Orleans, LA.	Mare Island Naval Shipyard, San Francisco, CA.
American Ship Building Company, Toledo, OH.	Philadelphia Naval Shipyard, Philadelphia, PA
Bethlehem Steel Corp, Beaumont, TX.	Portsmouth Naval Shipyard, Portsmouth, NH.
Coastal Dry Dock & Repair Corp, Brooklyn, NY.	Puget Sound Naval Shipyard, Seattle, WA.
Curtis Bay Repair Facility, Coast Guard Base, Baltimore, MD.	
FMC Corp, Portland, OR.	
Galveston Shipbuilding Co, Galveston, TX.	
Levingston Shipbuilding Co, Gulf Port, Port Arthur, TX.	
Marathon LeTourneau Co, Brownsville, TX.	
Northwest Matine Iron Works, Portland, OR.	
Tacoma Boatbuilding Co, Inc, Tacoma, WA.	
Triple "A" Machine Shop, Inc. San Francisco, CA.	

To produce the base case the analysis indicates that from 10 to 14 private yards are necessary for Constraint Sets 1 through 5, although the program will support a maximum of 18

yards at what is judged to be the base subsistence level. No naval shipyards are required.

The solution with no constraints is the same as that which places only maximum labor force constraints, indicating that at the given rate of construction the base case does not strain the mobilization capacities of the yards. Only six of the nine Category I yards are used, in addition to one Category II yard, two Category III yards and one Category S yard.

When labor force rate of expansion restrictions are imposed the number rises to 13 or 14 yards, so that in the runs based on all three sets--medium, low, and high rates--these constraints bind. It now requires 7 or 8 Category I yards rather than six, as yards are denied awards because their labor forces cannot expand rapidly enough. Note that the Category S yards, which have neither maximum labor nor rate of expansion restraints, benefit from the rate restrictions on the relevant yards.

In general, Constraint Set 6 results must be interpreted in a different manner from the other five. In this run IDASAS distributes ship awards to yards until it brings their employment levels up to minimum subsistence levels. Hence, it may not distribute all ships to producers, if those yards which have the capability of producing unassigned ships have reached their subsistence level and remaining yards do not have the facilities or capability to construct those that remain. In the base case analyses only three ships were unassigned, but this figure will rise to higher levels for other cases. It is important, therefore, to understand that the purpose of the exercise is to maximize the number of yards at minimum operation levels, not just to build all the ships.

In the base case, Constraint Set 6 yields 18 yards, all private, which could be just maintained. Though this represents only a rough estimate, it confirms the conclusion made in

Chapter II that continuation of recent procurement trends will result in attrition of yards from the industry.[1]

To summarize: the base case is judged to be feasible with respect both to its facilities and labor requirements. Indeed, it is concluded that 10 to 14 yards would bracket the absolute minimum necessary, the latter figure being the number in the solution associated with what is designated as the most likely parameter set--Set 3. Only 8 of the 9 Category I yards would be used, and 2 each of the 5 Category II yards, the 11 Category III yards, and the 12 Category S yards. No naval shipyard need be used. Thus the industry could shrink considerably and still be able to maintain current force levels while satisfying commercial demand.

These results of the formal IDASAS analyses were not changed in the informal alteration of assignments to achieve prompt delivery of all ships. The number of ships not delivered on schedule can be easily accommodated by slight reshuffling within the categories, requiring no more yards to be used.

In Table 4-7 IDASAS results are presented for the trimmed base case program with Navy ships only included. With no effective labor constraints binding, IDASAS asserts that only four of the Category I yards could build the base case naval ship program. With labor force expansion rate constraints this number rises to between 5 and 8, all private. The program would be sufficient to maintain about 13 yards at minimum viable employment levels. This steady-state Navy program, therefore, poses no challenge to shipyard capacity, and, indeed, taken by itself, would spell a period of severe attrition for the industry, even if IDASAS's ideal results were supplemented by

[1]Though Table 4-5 shows that all Category I yards could be supported, actual bidding would be likely to also lead to their attrition; indeed, actual bidding would be likely to yield an actual shipbuilding base smaller than 18 yards.

Table 4-7. BASE CASE, NAVAL SHIPS ONLY: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 581)

Shipyard Categories	Constraint Set 1: No Labor Constraint	2: Maximum Labor Force	3: Maximum Labor Force, 25 Percent Expansion	4: Maximum Labor Force, 19 Percent Expansion	5: Maximum Labor Force, 38 Percent Expansion	6: Maximum Yards
I	4	4	5	6	4	8
II	0	0	0	1	0	3
III	0	0	0	0	0	0
S	0	0	1	1	1	2
Total Private	4	4	6	8	5	13
Naval	0	0	0	0	0	0
Total Yards	4	4	6	8	5	13
Ships Delivered by 1995[a]	216	216	216	216	213	203
Ships Delivered after 1995[b]	1	1	1	1	4	14
Total Ships[a]	217	217	217	217	217	217

[a]Includes conversions.

[b]Number of ships scheduled for delivery after 1995: 1.

some desirable slack. Further, no alterations of these results by informal analysis is necessary in view of these conclusions.

2. Lowest Procurement Program

It would be expected, given the base case results, that the lowest case is also feasible, and, indeed, that its implementation would spell even greater attrition among the yards. The results do not disappoint that expectation, as Table 4-8 makes clear.

The results for all six parameter sets are almost identical with those of the base case. They differ only where differences in the types of ships produced in the cases or the different sequence in awards requires slightly greater use of Category S yards in 2 of the 5 yard-number minimization sets. Category I usage is identical, Category II usage falls by 1 in Constraint Set 3, and Category III usage is constant over all cases. Hence, for practical purposes, the minimum industry required for this case is not significantly different from that needed for the base case.

Set 6 reveals that the net result of the changes from the base case in number of ships, types of ships and award years did not register in the number or pattern of yards used. The program might barely sustain 18 private yards with almost all ships built. The reason for this unchanged result (one would expect the lowest case to be able to support fewer yards than the base case, since it has fewer ships) appears to lie in the different award pattern.

In terms of industry impact the base and lowest cases are about the same. Certainly, neither case represents a surge in demand, and neither threatens to approach the exhaustion of industry response potential.

Once more, no informal changes in yard numbers are required. The numbers of ships not delivered on schedule in Sets 1 through 5 are negligible and can be interjected into yards' loadings with no changes in yard numbers.

Table 4-8. LOWEST CASE: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 518)

Shipyard Categories	Constraint Set 1: No Labor Constraint	2: Maximum Labor Force	3: Maximum Labor Force, 25 Percent Expansion	4: Maximum Labor Force, 19 Percent Expansion	5: Maximum Labor Force, 38 Percent Expansion	6: Maximum Yards
I	6	6	8	7	8	9
II	1	1	1	2	1	4
III	2	2	2	2	2	2
S	1	1	3	3	3	3
Total Private	10	10	14	14	14	18
Naval	0	0	0	0	0	0
Total Yards	10	10	14	14	14	18
Ships Delivered by 1995[a]	354	363	362	362	363	361
Ships Delivered after 1995[b]	3	4	5	5	4	6
Total Ships[a]	357	367	367	367	367	367

[a]Includes conversions.

[b]Number of ships scheduled for delivery after 1995: 3.

The results for the trimmed lowest case, in which no commercial or Coast Guard ships are built, are presented in Table 4-9. IDASAS predicts that only 3 Category I yards would be necessary if no labor constraints were imposed or if only labor force ceilings were used. When ceiling rates of expansion are imposed 6 to 7 yards are needed including 4 or 5 Category I yards. Practically all ships are built on schedule, and the few that remain can be accommodated in the yards used in the solution. No informal supplementary analysis is needed. Finally, with all but 8 ships assigned on schedule, this naval-only program could keep only 6 Category I yards viable at subsistence levels plus 2 Category S yards.

Hence, the naval-ships-only trimmed base and lowest case programs would require only 5 to 8 yards to effect production, and would in both cases imply severe hardship for the industry.

3. <u>Intermediate Case Procurement Program</u>

The results for the intermediate case are shown in Table 4-10. For Constraint Set 1--in which only facilities restraints are operative--the minimum number of private yards needed rises from the 10 of the base case to 14. In addition, 2 naval shipyards are called upon to construct specialized ships or for conversions of large ships.

Imposition of maximum work force restraints under Constraint Set 2 raises the number of private yards needed to 16 from the base case's 10, and, in addition, brings in 1 more naval shipyard for a total of 3, compared with 0 for the base case. Hence, 19 yards are required, or almost double the base case number.

With the imposition of maximum labor expansion rates as well as labor force levels in Sets 3, 4, and 5, yard requirements rise. For the most likely case--Set 3--19 private and 3 naval shipyards are needed, or 22 yards, compared with 1-

Table 4-9. LOWEST CASE, NAVAL SHIPS ONLY: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 518)

Shipyard Categories	Constraint Set 1: No Labor Constraint	Constraint Set 2: Maximum Labor Force	Constraint Set 3: Maximum Labor Force, 25 Percent Expansion	Constraint Set 4: Maximum Labor Force, 19 Percent Expansion	Constraint Set 5: Maximum Labor Force, 38 Percent Expansion	Constraint Set 6: Maximum Yards
I	3	3	5	5	4	6
II	0	0	0	0	0	0
III	0	0	0	0	0	0
S	0	0	2	2	2	2
Total Private	3	[illegible]	7	7	6	8
Naval	0	0	0	0	0	0
Total Yards	3	3	7	7	6	8
Ships Delivered by 1995[a]	152	152	148	147	148	141
Ships Delivered after 1995[b]	3	3	4	5	4	11
Total Ships[a]	152	152	152	152	152	152

[a] Includes conversions.

[b] Number of ships scheduled for delivery after 1995: 3.

Table 4-10. INTERMEDIATE CASE: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 700)

Shipyard Categories	Constraint Set 1: No Labor Constraint	2: Maximum Labor Force	3: Maximum Labor Force, 25 Percent Expansion	4: Maximum Labor Force, 19 Percent Expansion	5: Maximum Labor Force, 38 Percent Expansion	6: Maximum Yards
I	9	9	9	9	9	9
II	2	3	4	4	4	4
III	2	2	2	4	2	5
S	1	2	4	7	3	12
Total Private	14	16	19	24	18	30
Naval	2	3	3	3	3	2
Total Yards	16	19	22	27	21	32
Ships Delivered by 1995[a]	554	553	548	551	553	432
Ships Delivered after 1995[b]	14	15	20	17	15	136
Total Ships[a]	568	568	568	568	568	568

[a]Includes conversions.

[b]Number of ships scheduled for delivery after 1995: 13.

private yards in the base case--a 57 percent expansion in number of yards to produce a 31 percent increase in ship numbers. The number of private yards responds sensitively to the reduction in maximum allowable labor force rate expansion in Set 4 by rising to 24, which, with the 3 naval yards, yields a total of 27 yards. When the ceiling is lifted, yard numbers rise from Set 3's 17 private to 18. With the 3 naval shipyards, these provide a total of 21 yards, compared with the base case level of 13. In all 5 cases, naval yard employment levels for new construction rise to a maximum total of 16,000 for the 3 combined, which seems quite feasible.

In each of these 5 solutions all Category I yards are used, Category II yard usage varies between 2 to 4, whereas Category III yard usage is between 0 and 4. Category S yards are quite variable in numbers used, lying between 1 and 7.

In summary, in the minimization-of-yards analyses, the study concludes that the intermediate case would require 14 to 24 private yards, depending importantly upon the expandability of labor supplies. The most likely ideal minimum estimate is 19 private yards. Further, 3 naval shipyards will be involved in conversion and new construction. Finally, the study concludes that this program could support at least 30 private yards at subsistence levels, with sufficient ship awards left over to raise them somewhat above those levels.

The trimmed, naval-ships-only solution for the intermediate case is given in Table 4-11. Under labor rate expansion constraints, 15 or 16 private yards are necessary to produce the military ships in the intermediate case in the IDASAS run, compared with 17 to 24 when commercial ships are included. For the "most likely" constraint set, there are 16 private yards for the Navy-only run and 19 for all ships. Moreover, only 2 naval shipyards are needed instead of 3 for the more inclusive program.

Table 4-11. INTERMEDIATE CASE, NAVAL SHIPS ONLY: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 700)

Shipyard Categories	Constraint Set 1: No Labor Constraint	2: Maximum Labor Force	3: Maximum Labor Force, 25 Percent Expansion	4: Maximum Labor Force, 19 Percent Expansion	5: Maximum Labor Force, 38 Percent Expansion	6: Maximum Yards
I	6	8	8(1)[b]	8(1)[b]	8(1)[b]	9
II	1	1	4	3(1)[b]	3(1)[b]	4
III	0	0	0	0	0(1)[b]	3
S	0	1	2(2)[b]	2(2)[b]	2	4
Total Private	7	10	14(17)[b]	13(17)[b]	13(16)[b]	20
Naval	1	2	2	2	2	2
Total Yards	8	12	16(19)[b]	15(19)[b]	15(18)[b]	22
Ships Delivered by 1995[a]	339	337	331	329	333	258
Ships Delivered after 1995[c]	14	16	22	24	20	95
Total Ships[a]	353	353	353	353	353	353

[a]Includes conversions.

[b]Amended by informal analysis.

[c]Number of ships scheduled for delivery after 1995: 13.

These reduced yard usages do result in higher numbers of ships undelivered by 1995, although they remain small in absolute numbers. Some difficulty is encountered in placing long-hulled ships in those runs using constraint sets that feature labor rate expansion limitations. Obviously, from Table 4-10, some of these ships were built in the more inclusive program. By studying the pattern of exclusions among ship types in the naval-ships-only run with that of the naval-plus-commercial run, it was determined that the number of yards indicated in parentheses in Table 4-11 should be added to IDASAS results. With those additions, plus some changes of allocations within categories, it is judged that most of those ships can be constructed on schedule. This increases the yards required to a range of 16 to 17, with the most likely estimate 17, as far as private yards are concerned, plus 2 naval shipyards.

It is interesting to note that for the cases discussed thus far there is no constant overload above Navy-workload required yards imposed by nonmilitary loads. Using Constraint Set 3 as the most likely result under ideal conditions, the base and lowest cases required 7 or 8 more yards to accomplish the commercial program, whereas the intermediate case requires only 3. The ability to fit merchant ships into building positions between Navy ship awards is what permits this economy of yards needed.

Finally, it is judged that the naval-ship-only program can keep at least 20 private yards at bare levels of viability. Allocation of the 82 ships not built on schedule would bring them up to more comfortable levels. This compares with 30 private yards for the total program, with about 130 ships left for distribution to provide some buffer above subsistence.

These results imply that the intermediate program would still be a feasible maximum contingency case if some smaller yards were to fail, but that any losses of combatant-capable (Category I) yards would cause problems.

4. Highest Procurement Program

This case--broadly, building toward an 800-ship Navy in 1995--is found to be a true challenge to industry capacity, with, for the first time in the analysis, an inability to build on schedule some ships requiring specialized facilities. The results are presented in Table 4-12.

When no constraints other than facilities availability are operative, IDASAS finds that 17 private yards plus 4 naval shipyards are necessary. When maximum labor force levels are placed upon the allocation under Constraint Set 2 the number of private yards rises to 23, and total yards to 27. Finally, the imposition of the three alternative maximum labor force expansion rates raises the total of private yards needed to 24 or 25. If Constraint Set 3 is again used as a best estimate under ideal conditions, it is estimated that the highest program requirement--before informal adjustment for unbuilt ships--is 25 private yards plus 4 naval shipyards. Moreover, Constraint Set 6 indicates that 32 private yards could be kept at subsistence levels with 197 of the 672 ships unassigned. Hence, this program provides abundant support to the industry.

However, one is struck by the large number of ships left unbuilt by 1995 when labor constraints are included in the program. The distinctive qualities of all of these ships in the four labor-constrained runs is that they are either nuclear ships, complex combatants, or long-hulled ships for which no further capacity exists in the industry. In these solutions all 9 Category I yards are being used to capacity, as are the 4 Category II yards with large building positions. Moreover, all 4 naval yards are being used at levels which imply total employment of about 50,000--certainly an optimistic view of their expandability of labor force.

Hence, IDASAS results in fact indicate a shortage of appropriate capacity that the informal analysis confirms. It

Table 4-12. HIGHEST CASE: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 821)

	Constraint Set					
	1	2	3	4	5	6
Shipyard Categories	No Labor Constraint	Maximum Labor Force	Maximum Labor Force, 25 Percent Expansion	Maximum Labor Force, 19 Percent Expansion	Maximum Labor Force, 38 Percent Expansion	Maximum Yards
I	9	9	9	9	9	9
II	3	4	4	4	4	5
III	2	4	5	5	5	6
S	3	6	7	7	6	12
Total Private	17	23	25	25	24	32
Naval	4	4	4	4	4	4
Total Yards	21	27	29	29	28	36[b]
Ships Delivered by 1995[a]	663	641	624	613	645	466
Ships Delivered after 1995[c]	9	31	48	59	27	206
Total Ships[a]	672	672	672	672	672	672

[a] Includes conversions.

[b] 36 was the number of yards input; i.e. all yards available to IDASAS were used here.

[c] Number of ships scheduled for delivery after 1995: 9.

is concluded therefore--especially in view of the fact that the results are truly minimum estimates--that the highest program is not feasible within the 14 year period envisaged.

Interestingly, in the three smaller cases already analyzed, the main constraints that effectively bound the solutions were the limited rates at which the labor forces were judged capable of expanding each year. In the highest case, however, the main constraint becomes the maximum employment level the yards are assumed to be able to reach. That is, true capacity limitations caused by the size of the yards are operative. These constraints are supplemented by the lack of facilities to build nuclear, other combatant, and large ships in yards located in regions where labor supplies are available. The stringencies, which began to be encountered in the intermediate case, become truly limiting in the highest case (given the 14-year time limit).

In Table 4-13 are displayed the IDASAS results for the naval-ship-only portion of the highest case program. From Constraint Set 1 it is seen that, as in the extended case displayed in Table 4- 12, sufficient building positions exist to build the whole program. However, those positions necessary to build some nuclear, other combatant, and long auxiliaries are located in yards which will reach maximum employment levels and/or employment expansion rates before all such awards are made. Hence, this lack of industry capability reasserts itself, as in Table 4-12, and the program is judged to be infeasible in the 14 year period envisaged.

The feasible portion of the program can be built by 19 to 21 private yards under ideal time-phasing, compared with 24 to 25 yards for the all-inclusive highest case. The most likely case--Constraint Set 3--yields 19 versus 25, so that the MARAD overload requires about 6 private yards.

Essentially, the highest case could support the entire shipbuilding base with facilities for ocean-going or large

Table 4-13. HIGHEST CASE, NAVAL SHIPS ONLY: SHIPYARDS REQUIRED UNDER SIX CONSTRAINT SETS (FY 1995 Force Level: 821)

Shipyard Categories	Constraint Set 1: No Labor Constraint	2: Maximum Labor Force	3: Maximum Labor Force, 25 Percent Expansion	4: Maximum Labor Force, 19 Percent Expansion	5: Maximum Labor Force, 38 Percent Expansion	6: Maximum Yards
I	9	9	9	9	9	9
II	2	3	4	4	4	4
III	0	1	2	3	3	5
S	1	2	4	5	4	10
Total Private	12	15	19	21	20	28
Naval	4	4	4	4	4	4
Total Yards	16	19	23	25	24	32
Ships Delivered by 1995[a]	457	430	408	401	421	333
Ships Delivered after 1995[b]	9	27	49	56	36	124
Total Ships[a]	457	457	457	457	457	457

[a] Includes conversions.

[b] Number of ships scheduled for delivery after 1995: 9.

Great Laker capacity. If only naval ships were built, 28 private and 4 naval yards would be capable of minimum operations, with about 115 ships for some buffering. This compares with 32 private and 4 naval shipyards in the all-inclusive highest case, with 197 ships left for award.

5. Summary

Table 4-14 summarizes the results of the feasibility analyses for the four procurement cases. The results of Constraint Set 3 should be considered as the "most likely" results under current conditions. The interval of procurement programs analyzed under this constraint set leads to a range for minimum yards required of 14 to 29, with the understanding that the last figure--for the highest case--would not produce the program by 1995.

Table 4-14. SHIPYARDS REQUIRED TO BUILD PROCUREMENT CASES UNDER SIX CONSTRAINT SETS

Constraint Set (See pp. 4-23/25)	Base Case (581 Ship Navy)	Lowest (518 Ship Navy)	Intermediate (700 Ship Navy)	Highest (821 Ship Navy)
1	10	10	16	21
2	10	10	19	27
3	14	14	22	29
4	14	14	27	29
5	13	14	21	28
6	18	18	32	36

Table 4-15 lists similar results for the stripped-down, Navy-only components of the procurement cases. The range for

Table 4-15. SHIPYARDS REQUIRED TO BUILD NAVAL-SHIPS-ONLY COMPONENTS OF THE PROCUREMENT CASES UNDER SIX CONSTRAINT SETS

Constraint Set (See pp. 4-23/25)	Base Case (581 Ship Navy)	Lowest (518 Ship Navy)	Intermediate (700 Ship Navy)	Highest (821 Ship Navy)
1	4	3	8	16
2	4	3	12	19
3	6	7	19	23
4	8	7	19	25
5	5	6	18	24
6	13	8	21	32

Constraint Set 3 is 6 to 23 yards, with the latter figure representing an infeasible program in the 14 year period considered, even if no commercial ships were constructed.

It is clear that the current industry is easily capable of maintaining current force levels, as approximated by the base and lowest cases, and that the shrinkage predicted in Chapter II could proceed to a rather considerable extent without impinging on this capability.

The 700-ship force level of the intermediate case is also attainable by FY 1995, though naval yards and some private yards now devoted only to repair would have to return to new construction activity. A few small commercial-capable yards could fail without changing this conclusion, but failure of any major combatant-capable yards could call it into question.

The highest case defines the limits of U.S. shipbuilding industry capacity; it's 821 ship force level is not quite attainable by FY 1995 under current conditions. Shortages of nuclear, large-hull, and combatant capacity are behind this, rather than a simple shortage of yards. As in the intermediate case, a few

small yards could fail without harm. Any losses of large yards would delay attainment of the force level target even further, though.

H. RESULTS OF THE TIME CONSERVATION ANALYSES

The 14 year period allowed for completion of programs in the feasibility analyses may have seemed a rather long one; it will be recalled that to study the possibility of reducing the time required for the programs, IDASAS accepted, for each of the 4 cases, the NAVSEA shipyard set as summarized in Table 4-5, 4-8, 4-10, and 4-12, but changed the award schedules over the years and by shipyard from those used by NAVSEA. It then used 4 alternative sets of planning factors and determined times to completion of the programs. The maximum labor force levels and the 25 percent per year labor force expansion maximum--that is, the constraints of Constraint Set 3--are operative in all runs. Moreover, it is assumed that the surge demands of the accelerated cases are foreseen sufficiently far in advance to expand (under government programs if necessary) weapons production capacity or other potential bottleneck materials or component capacities.

Since the NAVSEA award schedule is being relaxed for these runs, force level impacts cannot be specified precisely.[1] However, where IDASAS finds a program can be built in less time than is taken by NAVSEA, the force level results quoted by them would be reached or exceeded sooner than FY 1995. Thus the lowest and base cases can become "surge demand" cases.

1. Years Until Last Ship Is Built

In Table 4-16 are listed the numbers of years that elapse before the last ship in each program--it is always a nuclear

[1] IDA did not possess enough information about the current force makeup and its retirement schedules to make such specifications independently.

Table 4-16. YEARS TO COMPLETION OF ALL SHIPS UNDER FOUR SETS OF PLANNING FACTORS (MARAD PROGRAM OF 215 SHIPS BUILT WITH EACH CASE)

Planning Factor Set (See pp. 4-29/30)	Base Case (215 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
1. NAVSEA	12	10	14	16
2. NAVSEA x .8	10	10	14	14
3. NAVSEA x 1.2	13	10	16	17
4. Historical	12	10	15	16

ship--is finished. The planning factor Sets 1 through 4 were defined in Section D above and summarized in Table 4-4.

The results based on Factor Set 1, which contains the NAVSEA estimates of building periods, show that under current conditions the two smaller cases would require a minimum of 10 and 12 years to reach completion, while the two larger ones would require a minimum of 14 and 16 years, respectively.

Variations of the planning factors (20 percent less than NAVSEA-estimated ship construction periods, 20 percent more, and substitution of selected historical averages) show a sensitivity of 0 - 2 years in the programs' time-to-completion. The lowest case stands out particularly, with its 10-year duration unchanged in any excursion. This occurs because the number of ships built is small, and thus facilities are lightly loaded.

Planning factor changes primarily affect facility usage, having only a secondary impact on labor usage. In the lowest case, as in the feasibility analysis results presented above, the constraints which bind most are those on yard employment levels and growth rates.

The results for the other three programs, which contain more ships and thus require more facilities, generally show more intuitively appealing variations of 1 - 2 years when the building times are increased or decreased by 20 percent.

Little or no response occurs when planning factors including selected historical averages are used. This may occur because recent data was available for only a dozen or so ship types (and all the types may not be built in a given program), or because labor constraints again bind before facility limitations do.

In sum, IDASAS results indicate that a period of at least 10 to 16 years would be required to build 150 to 450 naval ships and 215 commercial ships. Taking steps to hasten the building process of *individual* ships, such as promoting standardization of naval ship designs, might cut as much as two years off this period. However, if slippages were to occur, perhaps caused by congestion in yards suddenly experiencing heavy demand for their products, the period might be extended by up to two years.

2. Years to Completion of All Nonnuclear Ships

Since the last ship constructed in each case reported in Table 4-16 was nuclear, but most program ships are not, it is interesting to study the times necessary to finish all those which are conventionally-powered. This may give a better picture of actual performance of the industry in terms of production times.

One complication arises in using this measure of build-up time, however. Many naval ships are complementary to one another, in the sense that they are built to function as task force teams, those battle forces frequently built around the aircraft carrier with cruisers as important components. To the extent these two types of ships are nuclear, neglecting their

completion times may give a false picture of the value of shorter completion times for nonnuclear ships. In Section H.4 the effect of substituting similar conventionally powered ships for these nuclear surface ships in the four programs is explored.

Table 4-17 presents the construction times for the nonnuclear portions of the 4 procurement programs. It is understood, of course, that some nuclear ships will also be completed within these periods.

Table 4-17. YEARS TO COMPLETION OF NONNUCLEAR SHIPS UNDER FOUR SETS OF PLANNING FACTORS (MARAD PROGRAM OF 215 SHIPS BUILT WITH EACH CASE)

Planning Factor Set (See pp. 4-29/30)	Base Case (217 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
1. NAVSEA	9	8	12	14
2. NAVSEA x .8	9	8	12	13
3. NAVSEA x 1.2	10	9	13	15
4. Historical	9	9	12	14

Comparison of Tables 4-16 and 4-17 shows that the nuclear components of the programs require 1 to 3 more years than their corresponding conventional components, with 2 years being the most common difference.

Planning factor variations have more effect on the conventional component of the lowest case than they do on the full program, but the general tendency still is for such variations to have the largest effect on cases where facilities are heavily used.

Judgments about the time premium required to build a nuclear Navy, as opposed to a conventional one, will be deferred to Section H.4. In Sections H.3 and H.4, the effectiveness of two policy options which might be implemented to hasten a given program's construction will be considered. Section H.5 will briefly discuss mobilization.

3. Years to Completion of Stripped-Down Naval-Ships-Only Programs

One plausible option would be the elimination of commercial and Coast Guard new ship construction in U.S. yards. It is assumed that such ships would be built in foreign yards, freeing labor and facilities for naval ship construction.

Such a scenario was presented for each case as part of the feasibility analysis discussed in Section G. Here it will be presented for each case using only the building times of Factor Set 1. The results are shown in Tables 4-18 and 4-19. Table 4-18, which is comparable to line 1 of Table 4-16, shows years to completion of the last ship (always nuclear) when the commercial program is not built, and Table 4-19, comparable to line 1 of Table 4-17, shows years to completion of the nonnuclear component of each program.

Table 4-18. YEARS TO COMPLETION OF NAVAL VESSELS ONLY WITH NO COMMERCIAL NEW CONSTRUCTION

Planning Factor Set (See pp. 4-29/30)	Base Case (217 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
NAVSEA	11	10	14	16

Table 4-19. YEARS TO COMPLETION OF NONNUCLEAR NAVAL VESSELS WITH NO COMMERCIAL NEW CONSTRUCTION

Planning Factor Set (See pp. 4-29/30	Base Case (217 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
NAVSEA	9	8	12	14

The results show a saving of only one year in total program time for the base case, and no saving in the other cases. Thus, it seems that legal actions to halt commercial new construction in the U.S. would *not* help accelerate a Navy buildup.

There appear to be two reasons for this somewhat surprising finding. One is that many smaller yards are qualified only to build commercial ships, and thus removal of commercial work does not result in their concentration on naval ships. Secondly, commercial ships have relatively short planning factors (building periods), and require relatively small amounts of labor. They do not place great demands on the facilities and labor of yards, and can thus be slotted in without difficulty when yards are only somewhat below the limits of their capacity.

4. Nonnuclear Substitution for Nuclear Surface Vessels

As a check on the indications drawn from Table 4-17, and as a second policy option, another scenario suggests itself for construction time analysis. If the times-to-completion of Tables 4-16 or 4-18, which depict requirements for programs with nuclear surface ships, were judged by policymakers to be too long, they might well opt to substitute nonnuclear surface ships for nuclear to conserve time. Of course, there may be

some tradeoff in mission effectiveness, but it will be assumed that time-cost dominates that benefit-loss in this case.

The following substitutions were made:

CV's for CVNs

CG-AS for CGN's and CGNA's.

Nuclear submarines, for which there are no (designed) conventional counterparts, remain in all the programs.

Table 4-20 summarizes the results, once more using both NAVSEA-determined shipyard sets to maintain comparability and Factor Set 1. Rather than showing years to full completion of the revised programs, which are driven by the nuclear submarine components in the lowest and base cases, years to completion of all *surface* ships are shown. In parentheses are displayed the times required to complete all *surface* ships when the nuclear ships are *not* converted (derived from the runs presented in Table 4-16).

Table 4-20. YEARS TO COMPLETION OF LAST SURFACE SHIP IN NON-NUCLEAR SUBSTITUTION PROGRAMS (MARAD PROGRAM OF 215 SHIPS BUILT WITH EACH CASE)

Planning Factor Set (See pp. 4-29/30)	Base Case (217 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
NAVSEA	9 (9)[a]	9 (9)[a]	12 (14)[a]	14 (16)[a]

[a]Nuclear program counterpart results in parentheses.

The results indicate that two years could be saved in construction of the intermediate and highest cases by turning to a conventional surface Navy, but that no time would be saved in the two smaller cases. This is not surprising, since the smaller cases contain only a few nuclear surface ships.

These results therefore support the indications, noted above, that about two years could be saved in a surge demand situation by turning to a conventionally powered Navy.

5. Some Tentative Insights into Mobilization Efforts

This study did not consider surge demand under conditions of mobilization, when certain sharp breaks in regime could be expected to occur in comparison to surge demand in the absence of mobilization. Standardization of ships and other accelerating factors in construction times, Defense Production Act Allocation powers to reduce lead times, multi-year procurement, wholesale labor shifts into the industry, government financing of new building positions and of weapons system production plants, and so forth, would change the climate of construction efforts considerably. Further, true mobilization usually occurs only after the outbreak of hostilities, and thus combat scenarios producing estimates of battle damage repair loads for the yards would be necessary, as well as estimates of the capacity which would have to be devoted to activation of ships now in mothballs.[1]

Although this study has not undertaken such a massive task, some results already obtained or readily obtainable may give certain limited insights into the industry's capacity to sustain such a program.

For example, each of the feasibility studies in Section G contains results obtained when only facilities restrain production (Constraint Set 1). If policies were implemented to ensure that the shipbuilding industry would not have difficulty obtaining labor (or materials and components), and if 14 years were

[1]Volume III of the 1978 *Interagency Maritime Study* [37] contains an interesting analysis of shipyard requirements for battle damage repairs and activation. Among other things, it notes that stockpiles of the parts necessary to activate inactive Navy ships were insufficient at the time of that study.

an acceptable mobilization period, then these results indicate that a surge up to a Navy force level of 821 ships would require at least 21 yards. Thus the current shipbuilding base seems adequate to support an admittedly rather leisurely mobilization (attrition of yards from the industry might change this).

Clearly, the fastest possible completion of a building program would be desirable in a mobilization. How much time would be saved if the industry could obtain any amount of labor desired, and if no commercial or Coast Guard ships were constructed? How much more could be saved if a conventional surface Navy were chosen instead of a partially nuclear one?

Table 4-21 provides answers to the first question for the same four sets of planning factors used previously. When compared to the results shown in Table 4-16, the measures effect time savings ranging from 0 to 4 years, with 2-1/2 to 3 years as a rough average. If one is optimistic about the possibility of shortening individual ship construction times (Planning Factor Set 2), construction of 150 to 450 naval ships might be completed in 7 to 11 years. If significant delays were encountered (Planning Factor Set 3), such construction would require at least 10 to 14 years.[1]

Answers to the second question (exercising the conventional surface Navy option in addition to labor-guarantee policies and a moratorium on commercial construction) are found in Table 4-22. They show the expected additional two-year savings (in comparison to Table 4-21) for the two larger cases, which contained many nuclear surface ships, and only one-year savings in the smaller cases, which contained very few.

[1]It is interesting to note in passing that the results in Table 4-21, obtained without labor constraints, support the argument made above that somewhat counterintuitive reactions to planning factor variations (e.g., Table 4-16) are the result of selective binding of the labor constraints. All the results of variations in Table 4-21 are in plausible directions and amounts.

Table 4-21. YEARS TO COMPLETION OF STRIPPED DOWN, NAVAL-SHIPS-ONLY PROCUREMENT CASES WITH NO LABOR CONSTRAINTS, UNDER FOUR FACTOR SETS WITH NO COMMERCIAL NEW CONSTRUCTION

Planning Factor Set (See pp. 4-29/30)	Base Case (217 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
1. NAVSEA	9	9	12	13
2. Navsea x .8	7	7	10	11
3. NAVSEA x 1.2	10	10	14	14
4. Historical	10	10	15	13

Table 4-22. YEARS TO COMPLETION OF STRIPPED DOWN, NAVAL-SHIPS-ONLY PROCUREMENT CASES WITH NO LABOR CONSTRAINTS AND NONNUCLEAR SUBSTITUTION FOR NUCLEAR SURFACE SHIPS WITH NO COMMERCIAL NEW CONSTRUCTION

Planning Factor Set (See pp. 4-29/30)	Base Case (217 Naval Ships Built)	Lowest Case (152 Naval Ships Built)	Intermediate Case (353 Naval Ships Built)	Highest Case (457 Naval Ships Built)
NAVSEA	8	9[a]	10	11

[a]Last ship was a submarine (i.e., nuclear). Last surface ship required 8 years for delivery.

These results bring out the inescapable fact that ship construction is a long process even under the most ideal conditions. Unless the construction period for major surface combatants and submarines, currently 6-8 years (even when conventionally powered), can be reduced, a balanced increase in Navy force levels cannot be achieved more quickly, regardless of the size of the shipbuilding industry.

It cannot be too strongly emphasized that these comments on possibilities under mobilization are *tentative*. The results presented do not take into account difficulties which would be encountered in obtaining materials, components, and weapons during a mobilization. They do not take into account the probable need to activate ships, or, in actual war, to accommodate battle damage repairs. These considerations would have a significant impact on the shipbuilding industry in an actual mobilization.

I. PRESENTATION OF NAVSEA ASSIGNMENT RESULTS AND COMPARISON

NAVSEA, acting for DoD agencies, provided the results of four notional assignments of the ships in the above procurement programs, which had been developed for other studies. Although most are not directly comparable to answers obtained from IDASAS, their presentation will be useful and instructive.

Table 4-23 presents the number of yards used by NAVSEA for each case, along with IDASAS results under Constraint Set 3 (facilities, employment ceilings, and a 25 percent per year expansion limit). One is immediately struck by the larger number of yards used by NAVSEA, especially in the base and lowest cases. This difference is in reality not surprising, since the two analyses were performed with different intentions. In these smaller cases, which simulate present procurement levels, NAVSEA's intent was to make realistic forecasts of the actual results of a bidding process undertaken by the current industry. In particular, they have taken into account the tremendous pressure on yards with few orders on their books to bid at or below breakeven cost levels (as shown in Chapter II). In the short run this will tend to spread even a small demand for ships among many yards, as the NAVSEA numbers indicate. In the long run yards will tend to go out of business, and careful examination of the NAVSEA results also confirms this. As current work is finished and the number of ships under construction approaches that

Table 4-23. COMPARISON OF NAVSEA AND IDASAS NUMBER-OF-YARDS RESULTS

	Base Case (581 Ship Navy)	Losest Case (518 Ship Navy)	Intermediate Case (700 Ship Navy)	Highest Case (821 Ship Navy)
NAVSEA	27	24	28	34
IDASAS (Constraint Set 3)	14	14	22	29

forecast in the lowest and base cases, many yards are forced to leave the industry. This, in combination with IDASAS results obtained above using Constraint Set 6 (maximize the number of yards supported), appears to definitely confirm the conclusion of Chapter II that industry attrition, even among major yards, is in the offing.

In contrast, all IDASAS results shown in Table 4-23 were obtained not as forecasts of normal peacetime trends, but as answers to the Variable Maximum Program analysis question "If the given program is the maximum to be undertaken in any national emergency, what is the *minimum* industry base necessary to produce it?"

Only NAVSEA's assignment of the highest case was done with a similar intent,[1] and the difference in results is relatively small here. A likely explanation of its source is NAVSEA's belief that a given yard can efficiently build only a few types of ships in large numbers. As noted above, this introduces an upward bias in the number of yards required, but it seems the bias is reassuringly small.

The intermediate case, as assigned by NAVSEA, is a venture into CMP analysis. Taking the highest case as a maximum

[1]Actually, they were interested in "building" it as fast as possible.

contingency for which a base must be prepared, this case was designed and allocated to simultaneously increase the force level and strengthen the industry so that the 821 ship force level of the highest case could be "jumped" to in only five years. Thus this result is also not directly comparable to that from IDASAS; nevertheless, the difference is again small.

Table 4-24 shows that the NAVSEA solutions, like those from IDASAS, make heavy use of the large Category I yards, while adjustments take place among the smaller and naval yards.

Table 4-24. BREAKDOWN OF YARDS USED IN NAVSEA SOLUTION INTO CATEGORIES

Shipyard Categories	Base Case	Lowest Case	Intermediate Case	Highest Case
I	9	9	9	9
II	5	4	4	4
III	5	4	5	6
S	7	6	8	11
Total Private	26	23	26	30
Naval	1	1	2	4
Total Yards	27	24	28	34
Ships Delivered by 1995	431	364	555	663
Ships Delivered after 1995	1	3	13	9
Total Ships[a]	432	367	568	672

[a]Includes conversions and non-military ships.

There is only one substantial disagreement between IDASAS and NAVSEA results. The reader may remember that IDASAS found it impossible to place a large number of nuclear, combatant, and large hull ships from the highest case, using NAVSEA's

ten-year award schedule. This was taken as an indication that the 821-ship force level target of that case might not be achievable by FY 1995. Discussions with NAVSEA have indicated that the disagreement stems from somewhat more stringent labor constraints (especially lower employment ceilings) used by IDASAS for some large, critical yards. Though the exact specification of these constraints is an empirical matter which has yet to be treated with full rigor, the optimistic nature of all IDASAS results reinforces the conclusion that specific capacity limitations may render the 821-ship, FY 1995 force level target unattainable.

Table 4-25 shows the time required by NAVSEA to complete the programs, along with IDASAS time-minimization results for Factor Set 1. Again, the fact that NAVSEA did not *intend* to minimize overall construction time in the base, lowest, and intermediate cases makes direct comparison with IDASAS results not fruitful. However, the two results are directly comparable for the highest case, where NAVSEA's intent was to build the case as quickly as possible. Given the disagreement over highest case results noted in the above comparisons of yards used, it may seem strange to find agreement here (16 years required by both analyses). This occurs because IDASAS, unable due to its more stringent labor constraints to complete the ships necessary to reach the force level target in the 14 year period specified by NAVSEA (FY 1982-95), is able to complete them in the extra two years which NAVSEA takes to finish the last few ships of the program. However, the optimistic nature of IDASAS results must again be emphasized, with the implication that materials shortages, management problems, or slippages due to technical difficulties might well push program completion time beyond 16 years.

Table 4-25. TIME REQUIRED BY NAVSEA AND IDASAS TO FINISH PROCUREMENT PROGRAMS

	Base Case (215 naval ships)	Lowest Case (152 naval ships)	Intermediate Case (353 naval ships)	Highest Case (457 naval ships)
NAVSEA Solution	15	16	15	16
IDASAS Solution (NAVSEA Factors)	12	10	14	16

J. SUMMARY AND CONCLUSIONS

This chapter has analyzed two broad questions:

(1) Is the U.S. shipbuilding base sufficient to provide for naval needs?

(2) Can Navy force levels be increased quickly?

In considering the first question, it was immediately clear that "naval needs" must be defined before a final answer can be given. Lacking such a definition, the Variable Maximum Program approach was adopted. Four alternative naval shipbuilding programs were used to bracket those needs.

The analyses indicate that achievement of a 500-700 ship Navy by FY 1995 would require a private shipbuilding industry consisting of an absolute minimum of 14 yards on the low end and 25 on the high, with the current industry being in the neighborhood of 40 yards. In addition, three naval yards would have to return to new construction work if the 700-ship Navy became the goal.

An 800-ship Navy probably could not be produced until FY 1997 or so under current conditions, even with heavy involvement of four naval yards and many private repair-only yards in new construction. This difficulty is caused not so much by

a simple shortage of yards, but rather by a shortage of yards with the facilities and labor to build nuclear, large-hull, and combatant ships.

The breakdown of yards needed into categories has shown the crucial part that nine large Category I (combatant capable) yards play in providing naval needs. Although failure of a couple of these in the upcoming troubled period for the industry (Chapter II) would not eliminate the ability to maintain current naval force levels, such failures would substantially weaken the industry's ability to effect large increases in those levels.

The comparison with results of NAVSEA assignments of the four cases reveals some optimism on their part about achievement of the 800-ship Navy, but general agreement with the findings of IDASAS when differences in intent and method are taken into account. In particular, their analyses confirm those of Chapter II (and those which used IDASAS) in predicting attrition of yards from the industry if recent naval and commercial purchase levels are maintained.

It is important to understand that costs have nowhere been taken into account in this analysis. It is not clear that real economic savings will occur if the programs are built in 14 shipyards rather than in 25 or 30. This depends upon extensive cost considerations which remain to be explored. Concentrating production in fewer rather than more yards may lead to congestion and management problems, for example.

In the analysis of time required to complete the naval programs, it was found that under current conditions a buildup involving the intermediate or highest case would require a minimum of 14 or 16 years, with the nuclear capacity shortage as a major constraint. Replacement of nuclear surface combatants with similar conventional designs would shorten buildup time by two years to 12 or 14 years, while elimination of commercial/Coast

Guard new construction would be of little or no avail. The lowest and base cases might be completed in around 10 years, but it must be remembered that these are designed as force level maintenance programs and not as buildup programs.

Very tentative insights into what might be possible under mobilization conditions were gained; even with conventional substitution for nuclear surface combatants, no commercial work, heavy use of priorities for materials, and policies to guarantee labor to critical yards substantial buildups would still require 10 or 11 years. The root of this long buildup period seems to be the long construction period of the modern warship. When eight years are required to build a nuclear carrier, and six for cruisers and submarines, truly rapid balanced increases in naval force levels seem unreachable.

Care should be taken with use of the numerical results quoted in this chapter. While the substantial agreement with NAVSEA's is reassuring, as were the results of the extensive sensitivity tests conducted, many important factors influencing the shipbuilding process could not be taken into account due to time and data limitations. In particular, implicit in the reduced program times achieved using policy options like conventional replacement of nuclear ships is the assumption that prompt and effective action will be taken by the government in anticipation of virtually certain shortages of materials, components, and weapons systems.

These results are reliable indications of possibilities, problems, and trends, then, but further and more detailed analyses would be required for their refinement to a level of precision suitable for use in actual planning.

Chapter V

THE CURRENT STATE AND MOBILIZATION POTENTIAL OF THE SOVIET NAVAL SHIPBUILDING INDUSTRY

A. DATA PROBLEMS

Several problems arise in dealing with the topics of this chapter. Most of the information is limited to shipyards that construct Soviet naval ships. For these shipyards, detailed, yard-by-yard performance and capacity data are not available in the detail used in examining the U.S. industry. Economic or financial data also are not available. Most of the information is intelligence and classified. It is consolidated in Appendix B of this study where the available supporting information is presented.

A best effort in this area permits one to be less specific than is possible in the analysis of the U.S. industry, and to deal only in aggregates. Moreover, it is often necessary to draw upon U.S. shipbuilding experience in seeking insights from the data, and thus may not be directly applicable. The results of this analysis must, therefore, be impressionistic in large part.

B. INDUSTRY CAPACITY AND PRODUCTION

One hypothesis flows from a close study of the U.S.S.R. production record in the last decade: The Soviet industry has been in a state of surge for at least that period of time, when the definition of that condition employed is that adopted for the U.S. industry and concerns only ship numbers. In

Table 5-1, Soviet production by major ship types is listed for the decade 1970-1979.

The category "large surface combatants" includes a wide range of naval ship types: aircraft carriers, nuclear and conventional cruisers, destroyers, frigates, and corvettes. Hence, the term "large" is meant to distinguish it from the second combatant category which is a force of very small ships, with largely coastal duties, whose existence is one of the important features that distinguish the Soviet Navy's structure from its U.S. counterpart. Such ships are of the patrol boat, mine warfare, or cutter types, and the U.S.S.R. has built up a substantial number of them, although their total tonnage is rather small, as is shown herein.

The overall production record revealed in Table 5-1 is impressive, although measured in displacement tonnage terms it is somewhat less formidable. Nonetheless, the U.S.S.R. produced in its yards for its navy an annual average of about 13 submarines, 11 large combatants, 53 small combatants, and 8 amphibious craft. This is about 85 ships per year sustained over a decade. The aggregate nonmilitary production is also impressive, although it must be recalled that average displacements would be much smaller than those of ships built in the western world. Large merchant ships--those over 1,000 gross registered tons--were produced at a rate of 72 per year, whereas smaller craft, which includes barges and inland water ships, averaged 56 per year. Over all types, the U.S.S.R. shipbuilding sector averaged about 128 ships per year over the last decade, which in comparison with U.S. output is judged to be a surge demand buildup.

This buildup occurred in the approximately 270 shipyards known to exist in the U.S.S.R., although over 100 of these are located on inland waterways, and hence produce smaller craft.

Table 5-1. ESTIMATED SOVIET SHIPBUILDING, BY CATEGORIES, 1970-1979

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Total
1. Naval:											
Submarines	18	12	13	12	13	11	10	13	13	12	126
Large Surface Combatants	12	11	7	12	9	13	12	12	12	11	111
Small Surface Combatants	64	67	61	48	48	52	51	50	49	48	538
Amphibious	16	14	8	4	9	4	7	6	5	4	79
TOTAL	110	104	89	76	79	90	80	81	78	75	852
2. Merchant:											
Large	75	82	68	86	64	80	70	67	65	64	721
Other	38	56	58	56	65	73	56	61	45	53	561
TOTAL	113	138	126	142	129	153	126	128	110	117	1,282

1. The Soviet Merchant Marine

Less information is available concerning nonmilitary ship production than military, presumably because of the former's greater dispersion and lesser interest to western intelligence agencies. However, the Soviet merchant marine has attained a cargo fleet size of over 10 million gross registered tonnage (GRT), much of it of foreign manufacture. Despite the high production levels of large merchant ships in Table 5-1, in 1976 only 35 percent of the fleet by tonnage was produced in the U.S.S.R., while East European communist countries accounted for 37 percent. Almost a third of Soviet output of commercial ships is believed to be exported under the impetus of substantial subsidization. For example, the Baltic yards export to Cuba, Algeria, Sweden, Norway, and West Germany. In international shipping circles, the Soviet fleet is an aggressive competitor for business and is becoming worrisome to western nations seeking to preserve the competitiveness of their merchant marine fleets.

2. Soviet Naval Ship Construction

In the last 15 years the U.S.S.R. has directed substantial effort into the improvement and modernization of shipbuilding facilities. It has built 4 new shipyards, expanding and modernizing 24 others. Of course, much of this has been devoted to the buildup and maintenance of the Soviet Navy.

Since 1950 all naval ships have been produced in some 30 Soviet shipyards. It is this subset of the total of approximately 270 that has major interest for this study, for it is directly involved in satisfying the surge naval demand reflected in Table 5-1.

These yards have over 75 shipways that are over 475 feet in length, and more than 90 building positions of this size, and all naval construction is performed in these yards. Most

of them specialize in the production of only one category of ship--submarines, large or small surface combatants, or amphibious craft. Specialization seems to be a more widespread characteristic of those yards than their counterparts in the U.S. This is even truer of the strict Navy versus commercial specialization that characterizes the Soviet sector. Total employment in these Navy-relevant yards is about 225,000 more than the U.S. shipbuilding industry taken as a whole.

a. Submarine Production

The Soviet Union's submarines are built by five shipyards all of which are nuclear-qualified and have built nuclear craft. Largest of the five is at Severodvinsk--perhaps the largest shipyard in the world. The employment force in these submarine yards totals about 70,000 workers.

b. Large Surface Combatant Production

In recent years Soviet output in this category has been concentrated in nine yards, five of which specialize in naval categories only. Over 80,000 workers serve in the labor force devoted to the production of these ships.

It has been noted that Soviet surface combatants are smaller than their U.S. counterparts, but the Soviet yards have produced almost twice as many as the U.S. Moreover, the U.S.S.R. tends to produce a larger number of ships in a class than the U.S. which, together with the numbers of ships produced each year, tempts the conjecture that constructive changes to update technology may not be as frequent as in U.S. naval ships. For example, over 40 ships of the GRISHA class--an FFL--have been completed and the GRISHA III is still in production. At one time three different yards produced it. Some 30 FRG KRIVAK are known to have been produced at four different yards. Series production of such lengths, without

continuous design changes, may permit the introduction of more specialized equipment than U.S. yards can adopt and may also lead to more learning-type economies.

c. Small Combatant Production

Over a dozen U.S.S.R. yards produce these small craft. Their existence springs from Soviet concern with control of contiguous waters. As Table 5-1 reveals, their numbers regularly account for over 60 percent of annual naval ship output.

d. Amphibious Warfare Ship Production

Only three or four yards currently produce these ships which range in size from less than 100 tons to over 13,000 tons displacement. Production has declined steadily over the last decade. The output of each of these yards is one or two per year currently.

C. NAVAL SHIPYARD PERFORMANCE

It is very difficult to obtain much solid evidence of the performance of the Soviet yards producing naval ships. Profitability, of course, is not applicable. Indeed, *prima facie* evidence of inefficiencies exists. For example, Soviet yards tend to be more integrated than U.S. yards, producing more of their supplies and components on site, in some cases possessing forges and even steel-making capacity. Given especially the greater standardization that characterizes Soviet ships, U.S. experience would indicate the existence of economies obtained by concentrating such production in specialist facilities. Other defense-related or U.S.S.R. specific advantages may flow from this decentralization, of course.

As in U.S. production, times to completion seem to reveal substantial variations for vessels in the same class. For

example, the GRISHA I FFL had an average keel-laying to delivery time of two years, but specific ships varied between 1.5 and 2.5 years. One large class of SSN boats averaged 27 months, but revealed a variation of 17 to 44 months. It is estimated that both the Moskva and Kiev took four years or more to construct. These times are customary performances by the industry in the light of U.S. experience, and the variation normal.

If these production times are related to the ships currently being produced and to available building positions, the results suggest that Soviet naval shipbuilding yards are now operated at near-full capacity. In U.S. terms, surge demand in that sense is being experienced. In order to increase production, additional building positions would likely have to be constructed.

However, this probably is not a full picture of mobilization capacity. By moving the construction of major combatants into nonmilitary shipyards, many building positions could become available. It is difficult to believe that yards which deliver over 70 ocean-going ships annually--substantially larger than the capacity of the U.S. industry--could not increase outputs of submarines and larger combatants. Of course, this judges capacity by building positions alone, ignoring other facilities, labor skills availability and materials-components bottlenecks. Little is known concerning these. Only rarely in recent history has the U.S.S.R. produced navy vessels outside the 30 designated yards, however.

Lastly, productivity seems to lag in the U.S.S.R. military shipyards. With a 225,000 employment level, compared with about 88,000 in the equivalent U.S. yards, workers per-ship or per-ton-produced are much higher in the U.S.S.R. This may indicate an even less capital-intensive industry than

in the U.S., a less capable labor force, poorer management, a less efficient supplier base, or some combination of all.

D. COMPARATIVE ANALYSIS OF U.S. AND U.S.S.R. SHIPBUILDING INDUSTRIES

1. Factors

Some of the difficulties of comparing the U.S. and U.S.S.R. shipbuilding industries have already been indicated. It is now necessary to develop these themes in more detailed fashion.

The U.S. shipbuilding industry, despite its extensive protection and subsidization, is acting within the discipline of a free market economy, its stance toward government that of a seller toward a customer, complicated by peculiar dual management institutions that have contributed to a certain adversary relation. As such, the industry must adjust its product mix, techniques, and structure to what is a highly cyclical demand of uncertain composition. Costs and productivity are continuing concerns to management, and rates of return on dedicated investment have a dominant role in dictating rates of retention or expansion of capacity.

In the Soviet command economy, the industry is otherwise. Soviet shipyards building naval ships are controlled by the Ministry of Shipbuilding--one of the nine defense industrial ministries. The industry is an arm of government licy, benefiting from the economic reflections of a national military policy that has placed great priority upon the development of sea power. Demand over the last decade has been high, and, equally important, stable. While cost considerations, no doubt, are not wholly neglected, they seem to have been less of a concern in shaping decisions than in the U.S. industry. Capacity expansion need not be dictated by wholly economic considerations; vertical integration may be introduced into

the yards to reduce production periods at greatly increased costs; diversification into other product lines may be introduced to absorb free time; noncompetitive allocations of orders may permit yards to specialize more than is possible in a free market economy; and labor supplies may present simpler problems in many thorny areas (e.g., turnover) than they do in liberal societies.

Within such different social frameworks, the validity of a comparison of costs, efficiency, labor turnover, employment levels, productivity, production periods, or investment levels is difficult to assess. These economic dimensions are defined for different "spaces", so to speak, and no metric to define distances between the industries in these respects is meaningful. Economic comparisons are largely unrevealing.

Why not, then, deal wholly with the physical aspects? A comparison of the number of building positions, outputs of ships, man-years per ship, construction times, estimated surge capacity in ships, and so forth, should eliminate many of the economic noncomparabilities. There is some value in this view, and the study largely follow its dictates. But it, too, presents some difficult issues. For example, some of these "physical" measures were already offered above as "economic" in nature, and others are not independent of economic considerations. A measure such as man-years per ship, for example, reflects capital/labor ratio decisions which have powerful economic motivation. Also, there are the data and security problems discussed earlier in this Chapter.

More importantly, however, even if physical measures were independent of economic structure and data were reliable and quotable, a different set of incomparabilities is faced. Product types differ between the nations, output is structured differently among product types, and those structures may change significantly when products are measured in different units.

In the remainder of this chapter the study will present comparisons of the U.S.S.R. and U.S. shipbuilding industries in such physical dimensions and highlight these problems in the discussion. The Soviet data will be restricted to those 30 yards that produce naval ships.

2. The Structures of the U.S. and U.S.S.R. Navies

One dramatic manner of presenting the quite different structures of the two naval forces, as well as the manner in which comparisons change with a change in units of measurement, is by means of Figures 5-1a and 5-1b, and 5-2a and 5-2b. When fleet size is measured in numbers of units, the U.S.S.R. Navy is much larger than the U.S. Navy. Note particularly that the U.S. has more aircraft carriers but the Soviets have more cruisers, destroyers and frigates. The U.S.S.R. shows some superiority in nuclear attack submarines. It reveals great superiority in numbers of mine warfare and amphibious ships, and diesel attack submarines, all of which are short-legged craft by modern standards. Overall, Soviet "superiority" registers as a 1,300-ship force versus a U.S. 550-ship force, or a rather frightening two to one superiority.

But, of course, such comparisons ignore the different functions of the navies and the characteristics of the ships, at least as they have existed until recent years. Coastal warfare as noted earlier has a great role in Soviet strategy, as does a strategic role for ballistic missile submarines, offensive operations against battle forces and convoys for attack submarines, and operations relatively close to home bases for many of its larger combatants. Except for the submarine role in strategic and offensive ocean warfare, U.S. naval power is organized around battle forces, with carriers and cruisers as core units, designed to function over sustained

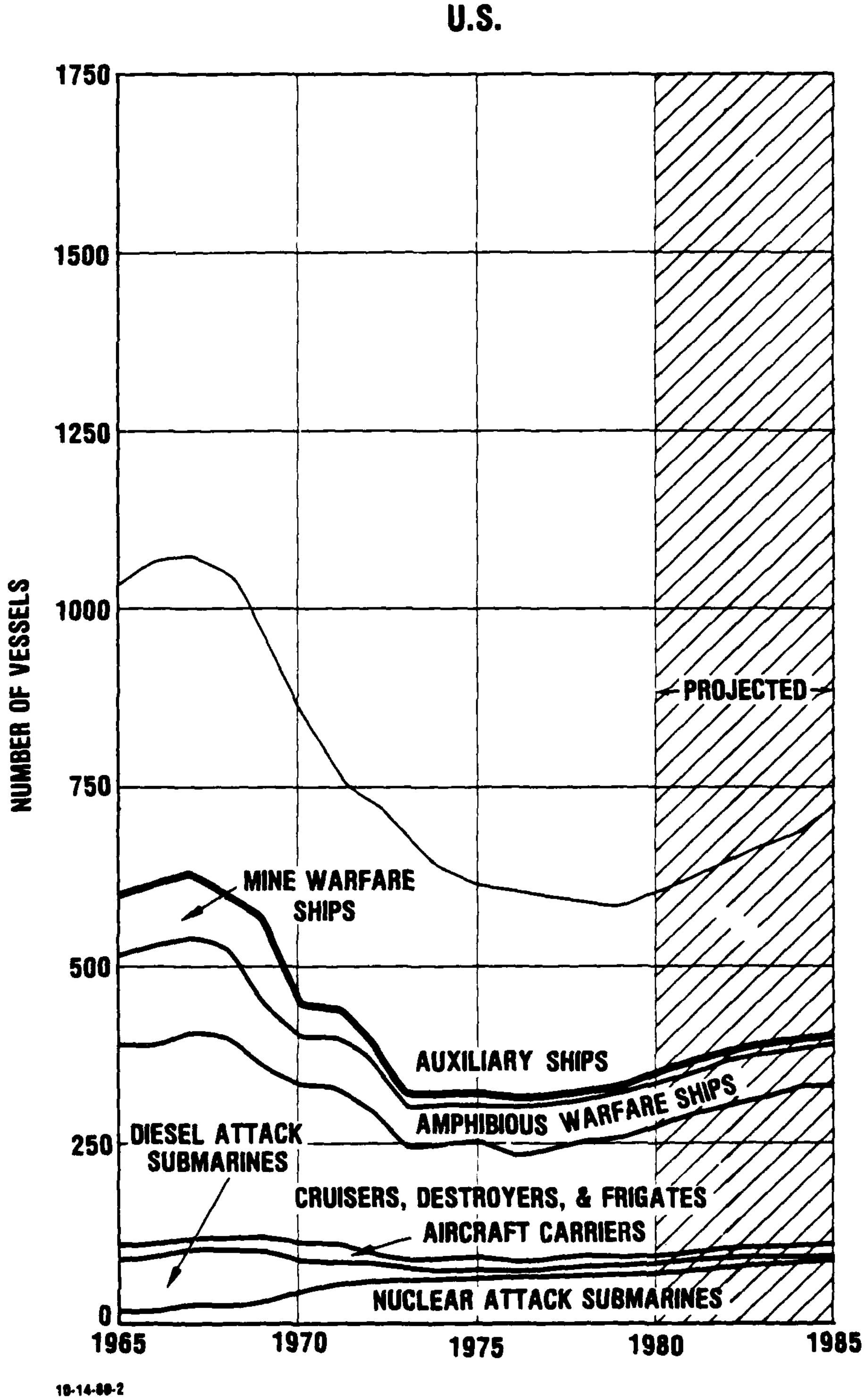

Figure 5-1a. GENERAL PURPOSE FLEETS, FORCE LEVELS, U.S. NAVY, IN NUMBERS OF SHIPS

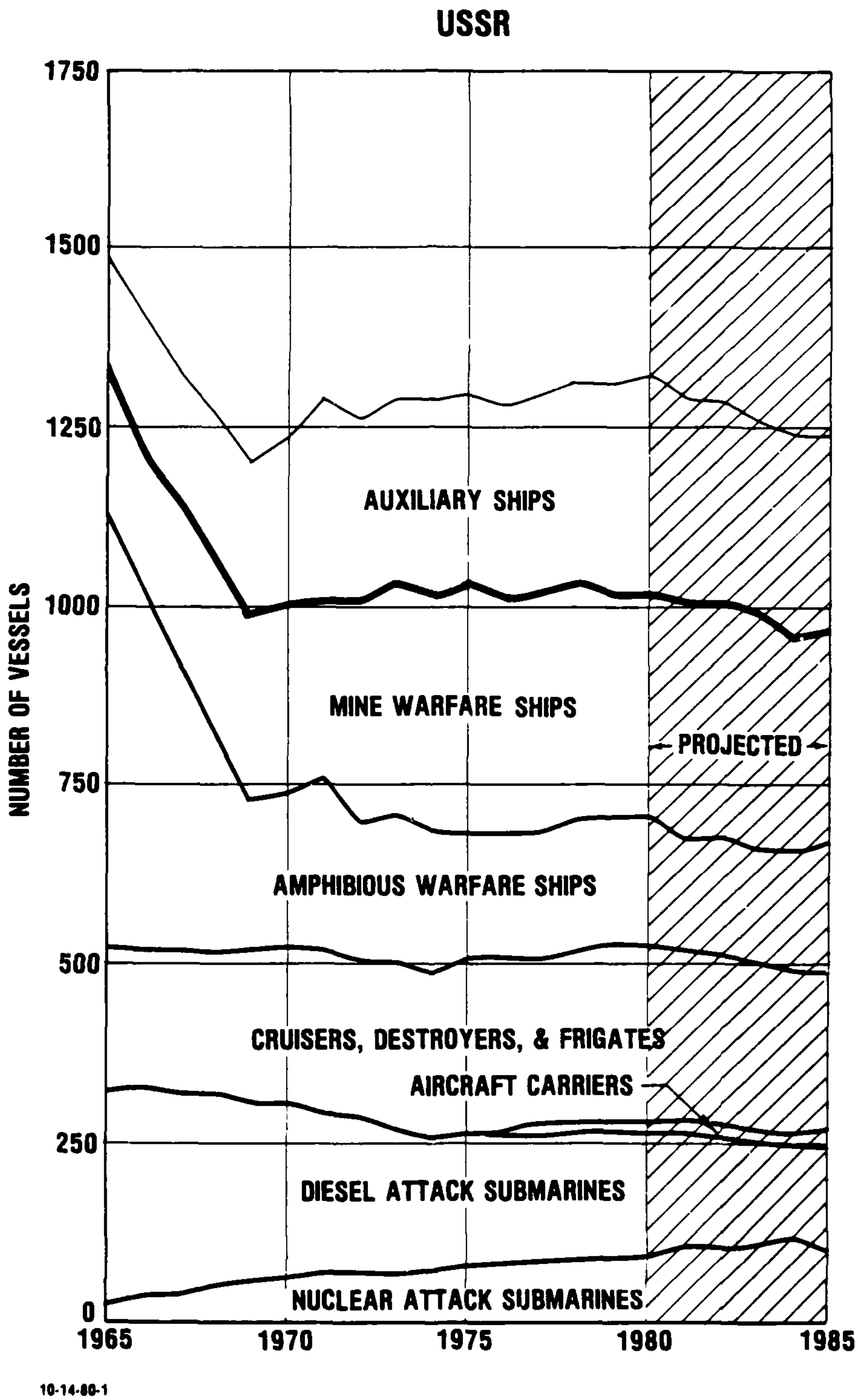

Figure 5-1b. GENERAL PURPOSE FLEETS, FORCE LEVELS, U.S.S.R. NAVY, IN NUMBERS OF SHIPS

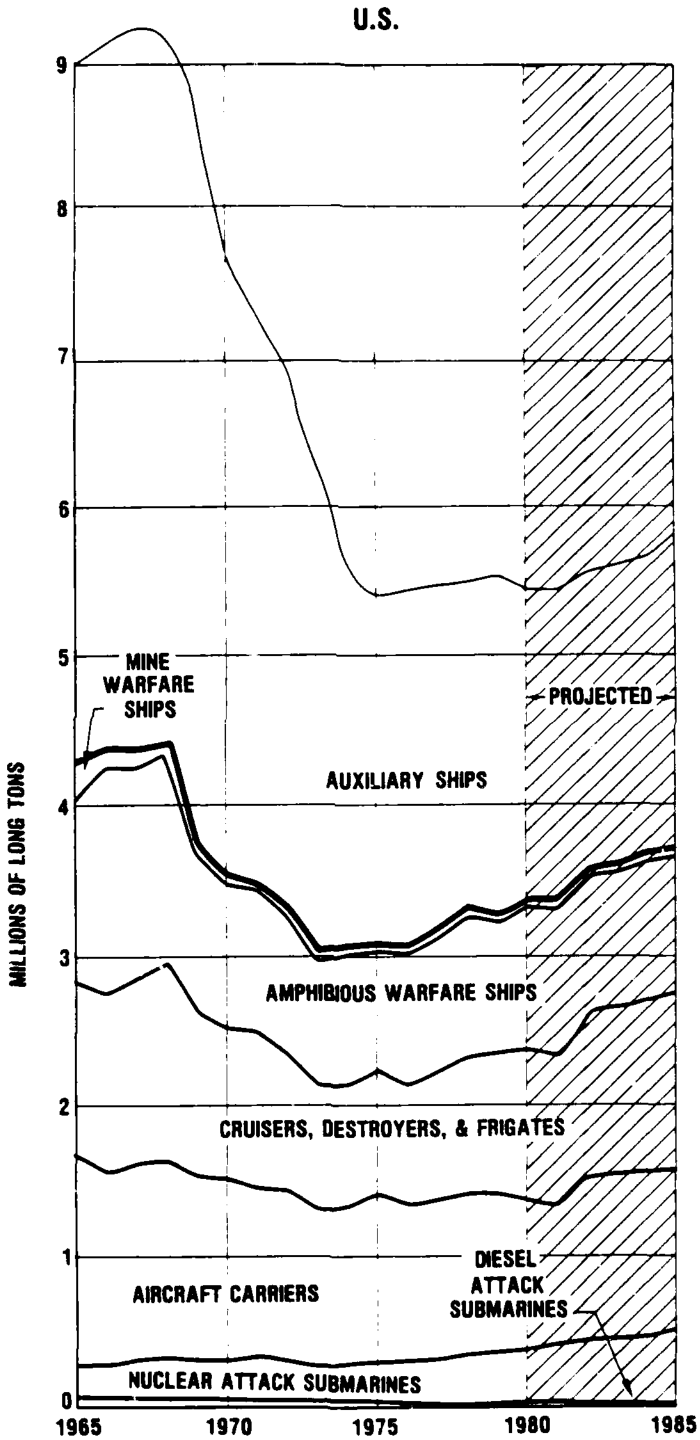

Figure 5-2a. GENERAL PURPOSE FLEETS, FORCE LEVELS, U.S. NAVY, IN TONNAGES

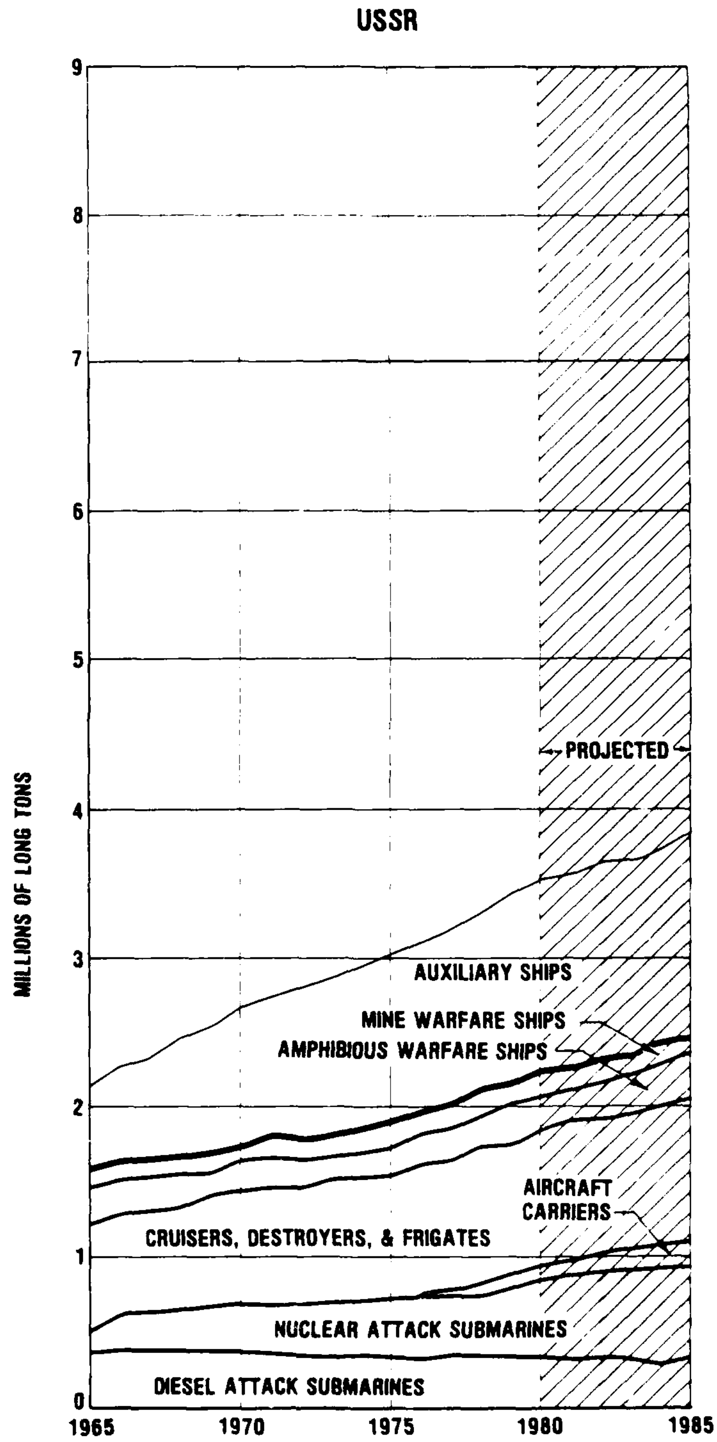

Figure 5-2b. GENERAL PURPOSE FLEETS, FORCE LEVELS, U.S.S.R. NAVY, IN TONNAGES

periods of time at long distances from CONUS or regional home bases. Coastal warfare is all but nonexistent as a foreseen function.

These functional differences are reflected in Figures 5-2a and 5-2b. The comparison of overall force levels, measured in long tonnage, reverses the conclusions from Figures 5-1a and 5-1b. The U.S.S.R. with about 3.5 million long tons in 1980 faces a superior U.S. Navy of 5.5 million long tons, or a 1:1.6 inferiority. The most interesting change in perspective is that of the relative displacements of the carrier fleets, the U.S. force far exceeding the Soviet carrier force. Gone, also, is Soviet superiority in other large combatants and amphibious warfare ships, and vastly diminished is its supremacy in mine warfare ships.

These comparisons suggest that comparative analysis of the industries supporting these diversely structured fleets should also be tempered by an appreciation of possible purposes of the construction.

3. The Recent Production Levels of U.S. and U.S.S.R. Naval Ships

Annual orders and deliveries of naval ships in the two nations reflect the structural differences of the fleets. The comparisons of annual deliveries (less auxiliaries) to the two fleets in terms of numbers and of thousands of long tons are displayed in Figures 5-3a and 5-3b. The Soviet emphasis on larger numbers of lighter ships yields, in 1979, a figure of 26 major ships delivered to the U.S.S.R. Navy, versus 11 for the U.S., but in tonnage terms this translates into 55,000 long tons for the U.S.S.R. compared with 100,000 for the U.S. The tonnage differences have narrowed since the early 1970s and are less favorable to the U.S.

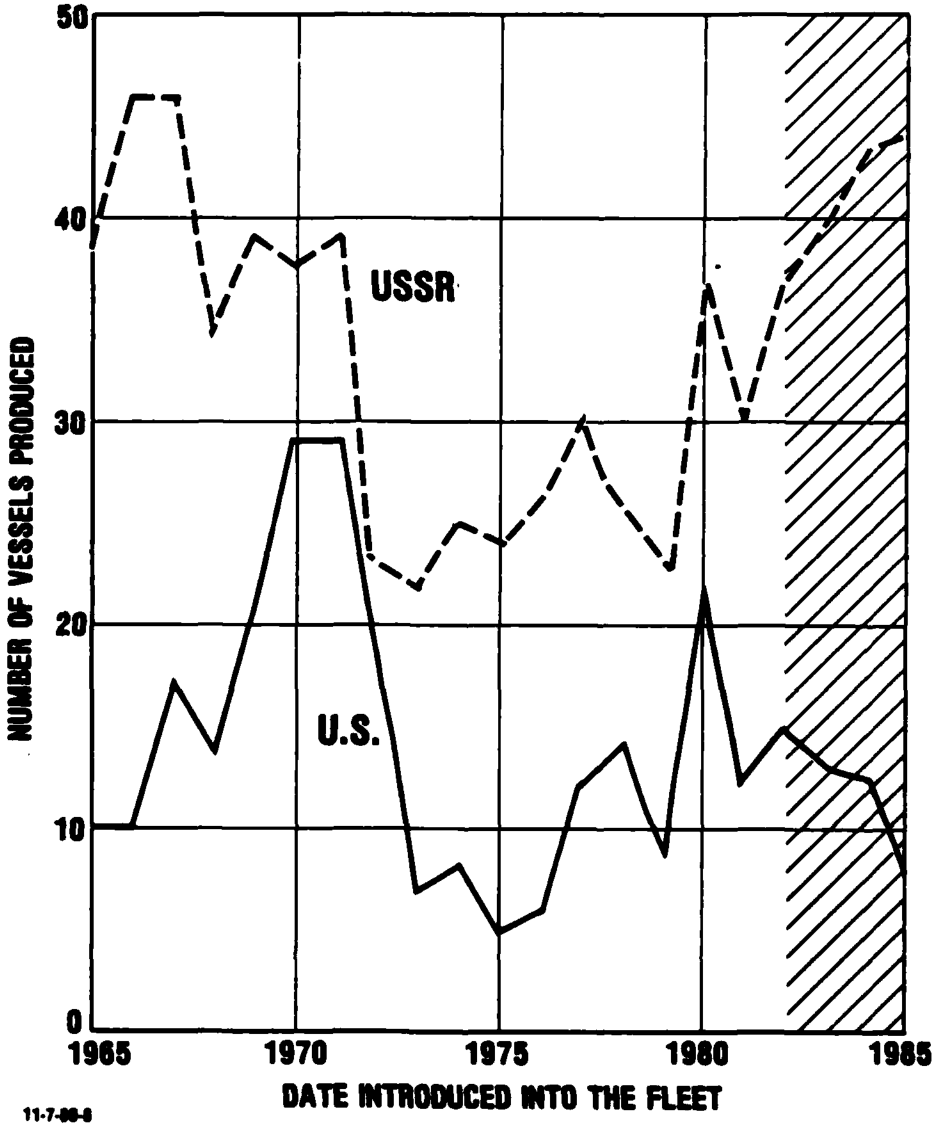

Figure 5-3a. GENERAL PURPOSE FLEETS, ANNUAL NAVAL SHIP PRODUCTION, LESS AUXILIARY SHIPS, NUMBERS OF SHIPS

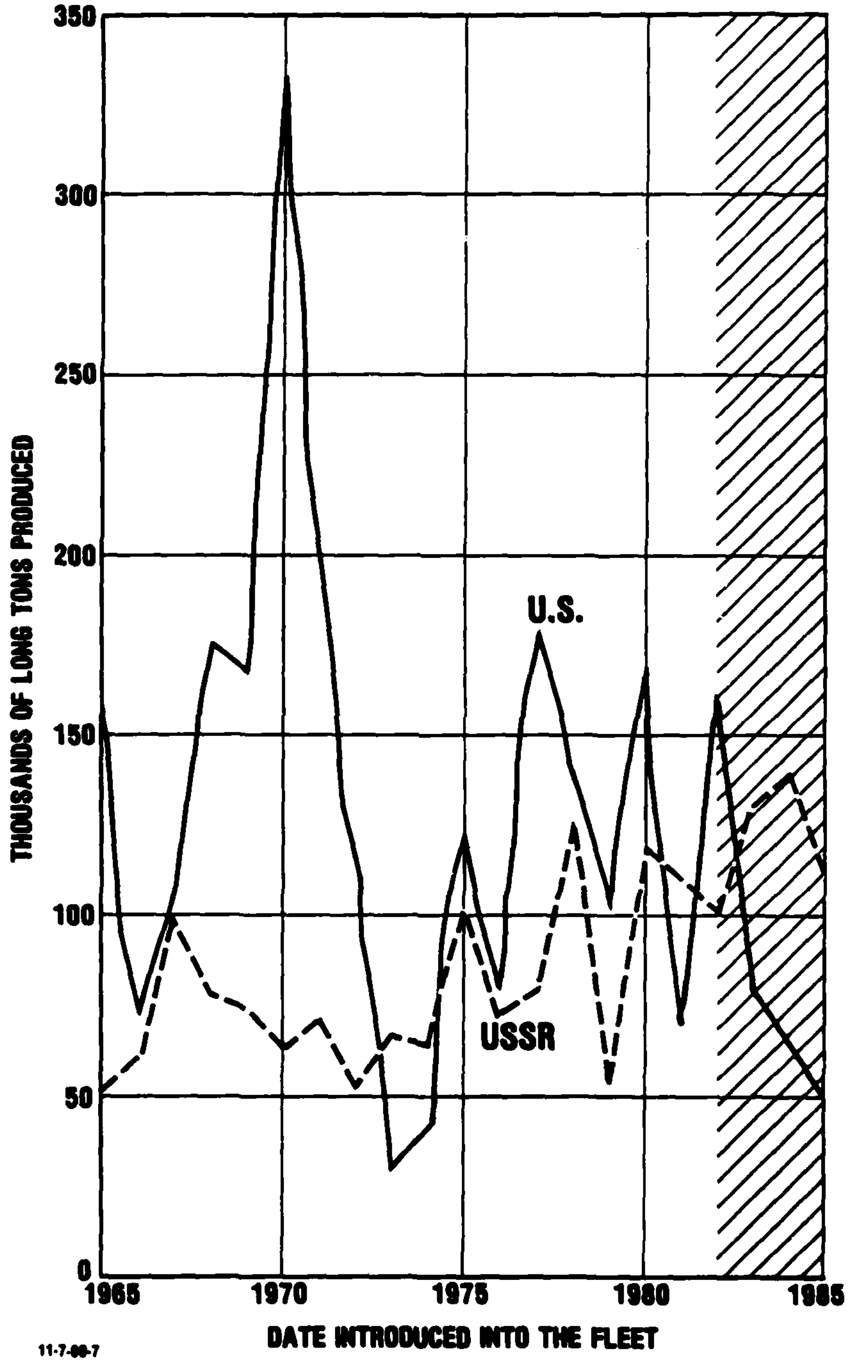

Figure 5-3b. GENERAL PURPOSE FLEETS, ANNUAL NAVAL SHIP PRODUCTION, LESS AUXILIARY SHIPS, TONNAGE

Perhaps a better comparison in terms of numbers may be derived from a study of Table 5-2. If we add together only the submarines and large combatants we get a better comparative figure to use against U.S. naval outputs less auxiliary/amphibious ships. In the 1970s, Russian shipyards turned out an average of 31 ships annually, nearly half of them submarines. Table 2-33, which projects U.S. orders forward to 1985, reveals an average annual figure of 13 such ships over the period, only about one-quarter of which are submarines. For the non-submarine component, tonnage comparisons reveal a much smaller discrepancy. The fleet trends are shown in Figures 5-2a and 5-2b and in Figures 5-3a and 5-3b.

4. Capacity of U.S. and U.S.S.R. Shipyards

Earlier it was indicated that about 90 building positions over 475 feet in length supported the Soviet naval output only. This is very close to the number of such building positions available for both naval and commercial ship production in the U.S. The U.S.S.R. has many more such positions in those yards it uses for nonmilitary construction, although their number is not known with accuracy.

The analysis of Chapter IV led to the conclusion that the U.S. capacity under peacetime and somewhat stressing conditions was sufficient to produce the intermediate case program, which averaged about 33 naval vessels per year plus 21 ocean-going nonmilitary ships per year. This included nuclear surface craft, which do not play a great role in the U.S.S.R. structure.

As developed in Appendix B, it can be said that present U.S.S.R. naval shipbuilding capacity could support current production levels plus perhaps 10 to 15 ships of the U.S. type. Soviet ships in the fleet being smaller and mostly nonmilitary, more units could probably be constructed on

Table 5-2. U.S./U.S.S.R. SHIPBUILDING DELIVERIES,NUMBERS OF SHIPS

Type	1970		1971		1972		1973		1974		1975		1976		1977		1978		1979	
	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR
1. Major Combatants	12	12	11	11	9	7	5	12	5	9	1	13	4	12	9	12	9	13	8	10
2. Submarines (including conversions)	7	18	9	12	10	13	7	12	5	13	6	11	2	10	5	13	5	12	2	12
3. Amphibious	13	16	12	14	6	8	0	4	0	9	0	4	2	7	1	6	1	5	1	4
Sub-Total (1-3)	32	46	32	37	25	28	12	28	10	31	7	28	8	29	15	31	15	30	11	26
4. Navy Auxiliaries	13	33	10	24	7	23	2	20	0	16	1	15	1	11	0	20	4	15	7	7
5. Merchant and Others	13	75	14	82	19	68	36	86	24	64	19	80	22	70	25	na	19	na	21	na
Sub-Total (4-5)	26	108	24	106	26	91	38	106	24	80	20	95	23	81	25	87	23	80	28	71
Sub-Total (1-5)	58	154	56	145	51	119	50	134	34	111	27	123	31	110	40	118	38	110	34	97
6. U.S.S.R. Small Combatants		64		67		61		48		48		49		51		50		46		48
TOTAL	58	218	56	212	51	180	50	182	34	159	27	172	31	161	40	168	38	156	39	145

these positions if desired. Beyond this is the uncertain potential for navy construction by the commercial ship producers, given the possibility of producing smaller combatants in their ways.

It is concluded, therefore, that *in terms of the mix of the ship types* it produces, the U.S.S.R., operating under surge demand conditions, may be closer to pressing upon the capacity of its industry than the U.S., but still possesses some residual capacity in the 30 yards that produce naval ships, and an unknown amount in yards producing commercial ships. However, if it surged into a program that put substantially greater emphasis on larger ships with longer building times, it would find its present capacity close to being filled.

E. CONCLUSIONS

Soviet Navy production is notable for its steady workloads, relatively constant structure within major categories, large numbers, and somewhat less impressive tonnage. Nonmilitary production shares these same characteristics. Ship production for the U.S. and U.S.S.R. reflects the different mix and functions of the fleets that have characterized each Navy until recent years. The U.S.S.R. emphasizes larger numbers of smaller ships than does the U.S. Building positions for the Soviet Navy are about equal to all ocean-going building capacity in the U.S., but it is believed that present Soviet shipyards are operating at, or near, capacity, reflecting the surge demand of the past decade. Substantial backup capacity exists in the sector that produces commercial ships. If the U.S.S.R. shifted emphasis to heavier ships, however, it would probably need new capacity.

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ANNEX

TASK ORDER NO. MDA903 79 C 0018: T-0-091

OFFICE OF THE UNDER SECRETARY OF DEFENSE

WASHINGTON D C 20301

RESEARCH AND ENGINEERING

15 September 1980

TASK ORDER
NO. MDA903 79 C 0018: T-0-091

TITLE: Naval and Commercial Ship Construction and US Shipbuilding Industry

1. This task order is for work to be performed by the Institute for Defense Analyses (IDA) for the Under Secretary of Defense for Research and Engineering.

2. BACKGROUND:

Senate Armed Services Committee Report of FY81 Authorization Report (June 1980) stated that they were dissatisfied with Secretary of the Navy's response to previous SASC request (FY80) regarding the subject, i.e., "considerably short of the comprehensive analysis which the committee had hoped to receive." The SASC report "requests that the Secretary of Defense, with the involvement of the Joint Chiefs of Staff and in conjunction with the Department's fiscal year 1982 budget submission, provide the Congress with a detailed assessment of the state of the US shipbuilding industry..." The report goes on to outline what the assessment should include.

3. OBJECTIVE:

The objective of this study is to provide to the DoD an analysis of the current state and mobilization potential of the US shipbuilding and support industries, and to compare them with those of the USSR to the extent the available data will allow, for the DoD's use in responding to the Senate request.

4. ADDITIONAL GUIDANCE:

a. Using recent available reports and data to be provided by the US Navy and Maritime Administration assess the current state of the US shipbuilding industry. Shipbuilding industry should be taken in the broad sense including naval and commercial; new ship construction and repair; shipyards, sub-contractor, component suppliers and technical support firms. To the extent the available data permit, the report should address the financial health of the industry, employment, productivity, facility investment, modernization plans, regulatory restriction, world competition, etc.

b. The study should address to the extent feasible based on the available data the relative ability of the Soviet Union and the United States to mobilize their respective shipbuilding industries with particular emphasis upon the near to medium term production of large numbers of ships. It is understood that IDA has recently completed an assessment of USSR shipbuilding capabilities which can be used as the basis for that part of this study. The report will clearly identify the areas of uncertainty about Soviet shipbuilding and point out the significance of the uncertainties for the desired comparison. Peacetime preparedness or contingency type of mobilization should be considered, i.e., a deliberate effort to build up the Fleet (US Navy and Merchant Marine) in a reasonable period of time, e.g., five years and ten years.

c. The study should indicate some alternative courses of action in the near and medium term to achieve and maintain the US Navy and Merchant Marine fleets at levels implied by the FYDP and some higher and lower excursions. The study should also indicate the potential impact of the proposed Fiscal Year 1982-1986 Five Year Shipbuilding Plan on reaching stated US Navy ship force level requirements and assess in general terms the adequacy of the FYDP program to maintain a shipbuilding industrial and support base at several levels including the desired level expressed by the Navy.

5. SCHEDULE:

The DoD's report is required to be submitted in conjunction with the Fiscal Year 1982 budget. Subject to timely availability of the necessary data, a draft (final) of the IDA report will be submitted to OUSDRE/Naval Warfare by 15-20 January 1981 with the final report published within two weeks after completion of review by OUSD(R&E). Interim informal progress briefings will be held in the last week of each month September thru December 1980, and on a need basis.

6. LEVEL OF EFFORT:

A total of $110,000 is authorized for this task, $10,000 in FY 1980 and $100,000 in FY 1981. The cost of funding authorized includes any costs for computer, consultants, subcontractual and other support which may be required for this task.

7. TECHNICAL COGNIZANCE:

This study is sponsored by USDRE. Technical cognizance for this task is assigned to OUSDRE/Naval Warfare.

8. SPECIFIC ADMINISTRATIVE INSTRUCTIONS:

a. If at any time during the course of this task, IDA identifies the need for changes in this task, such as additional resources, schedule modification, changes to emphasis of effort or scope, etc., as set forth in the above paragraphs, a report, with appropriate recommendations, will be submitted in accordance with

the terms of the IDA/WSEG Memorandum of Understanding of 12 March 1975 (and its successor) as applicable to the Executive Secretary, DOD-IDA Management Office, OUSDRE, with a copy to the sponsor or his project officer, as appropriate. Changes in this task will be made only with the approval of appropriate cognizant DoD officials.

b. This task will be conducted under Industrial Security Procedures in the IDA area. If certain portions of the task require the use of sensitive information which must be controlled under military security, the DOD-IDA Management Office will provide supervised working areas in which work will be performed under military security control.

c. A "need to know" is hereby established in connection with this task and access to classified documents and publications and security clearances necessary to complete the task will be obtained through the DOD-IDA Management Office unless otherwise instructed. Report distribution and control will be determined by the sponsor.

James B Statler

JAMES B. STATLER
Colonel USA
Executive Secretary
DOD-IDA Management Office

ACCEPTED Alexander H Flax
ALEXANDER H. FLAX
President, Institute for Defense Analyses

DATE September 17, 1980